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MONTHLY WEATHER REVIEW

VOLUME 44, No. 10

OCTOBER, 1916

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OCTOBER, 1916.

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NOTICE TO CONTRIBUTORS.

Contributions intended for publication in any given issue of the MONTHLY WEATHER REVIEW (e. g., January) should be in the hands of the Editor before the end of the next following month (e. g., February), if no illustrations are required. When the paper is illustrated, the manuscript and the copy for the illustrations must be submitted much earlier, in order to permit copy being prepared for the engraver by the end of the month.

REPRINTS are made up without covers in the original size and pagination of the REVIEW. They will not be furnished unless specifically REQUESTED WHEN THE MANUSCRIPT IS SUBMITTED.

MONTHLY WEATHER REVIEW

CLEVELAND ABBE, jr., Editor.

VOL. 44, No. 10.
W. B. No. 599.

OCTOBER, 1916.

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INTRODUCTION.

As explained in this Introduction during 1914, the MONTHLY WEATHER REVIEW now takes the place of the Bulletin of the Mount Weather Observatory and of the voluminous publication of the climatological service of the Weather Bureau. The MONTHLY WEATHER REVIEW contains contributions from the research staff of the Weather Bureau and also special contributions of a general character in any branch of meteorology and climatology.

SUPPLEMENTS to the MONTHLY WEATHER REVIEW will be published from time to time.

The climatological service of the Weather Bureau is maintained in all its essential features, but its publications, so far as they relate to purely local conditions, are incorporated in the monthly reports "Climatological Data" for the respective States, Territories, and colonies.

Since August, 1915, the material for the MONTHLY WEATHER REVIEW has been prepared and classified in accordance with the following sections:

SECTION 1.—*Aerology.*—Data and discussions relative to the free atmosphere.

SECTION 2.—*General meteorology.*—Special contributions by any competent student bearing on any branch of meteorology and climatology, theoretical or otherwise.

SECTION 3.—*Forecasts and general conditions of the atmosphere.*

SECTION 4.—*Rivers and floods.*

SECTION 5.—*Seismology.*—Results of observation by Weather Bureau observers and others as reported to the Washington office. Occasional original papers by prominent students of seismological phenomena.

SECTION 6.—*Bibliography.*—Recent additions to the Weather Bureau library; recent papers bearing on meteorology.

SECTION 7.—*Weather of the month.*—Summary of local weather conditions; climatological data from regular Weather Bureau stations; tables of accumulated and excessive precipitation; data furnished by the Canadian Meteorological Service; monthly charts Nos. 1, 2, 3, 4, 5, 6, 7, 8, the same as hitherto; Meteorological Summary and chart No. 9 of the North Atlantic Ocean for this month in 1915. Owing to the fact that ocean meteorological data are frequently not available for a considerable time after the close of the month to which they relate, the chart and text matter in connection therewith appear one year late.

In general, appropriate officials prepare the seven sections above enumerated; but all students of atmospherics are cordially invited to contribute such additional articles as seem to be of value.

The voluminous tables of data and text relative to local climatological conditions, that during recent years were prepared by the 12 respective "district editors," are omitted from the MONTHLY WEATHER REVIEW, but collected and published by States at selected section centers.

The data needed in Section 7 can only be collected and prepared several weeks after the close of the month designated on the title-page; hence the REVIEW as a whole can only issue from the press within about eight weeks from the end of that month.

It is hoped that the meteorological data hitherto contributed by numerous independent services will continue as in the past. Our thanks are specially due to the directors and superintendents of the following:

The Meteorological Service of the Dominion of Canada.
The Meteorological Service of Cuba.
The Meteorological Observatory of Belen College, Habana.
The Government Meteorological Office of Jamaica.
The Meteorological Service of the Azores.
The Meteorological Office, London.
The Danish Meteorological Institute.
The Physical Central Observatory, Petrograd.
The Philippine Weather Bureau.

The Weather Bureau desires that the MONTHLY WEATHER REVIEW shall be a medium of publication for contributions within its field, but such publication is not to be construed as official approval of the views expressed.

SECTION I.—AEROLOGY.

SOLAR AND SKY RADIATION MEASUREMENTS DURING OCTOBER, 1916.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Nov. 28, 1916.]

For a description of instrumental exposures, and an account of the methods of obtaining and reducing the measurements, the reader is referred to the REVIEWS for January, April, and May, 1916, **44**:2, 179, 180, and 244.

The monthly means and departures from normal values of Table 1 show that direct solar radiation intensities averaged about normal at Washington, D. C., slightly above normal at Lincoln, Nebr., and decidedly above at Madison, Wis., and Santa Fe, N. Mex. Noon intensities of 1.46 calories at Madison on October 10, and 1.53 calories at Lincoln on October 25, exceed any previous intensities measured at these stations in the month of October; while noon intensities of 1.57 calories measured at Santa Fe on October 19 and 21 equal any October reading previously obtained at that station.

TABLE 1.—*Solar radiation intensities during October, 1916.*

[Gram-calories per minute per square centimeter of normal surface.]

Washington, D. C.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
A. M.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Oct. 1					1.15	1.10				
6		1.13								
7		1.01	0.83	0.68	0.56					
8						0.53		0.48	0.44	
9		1.23								
10		1.39	1.35	1.24						
11		1.21	1.15	1.07						
12		0.92	0.80							
14			1.27	1.18						
21		1.37	1.26	1.15						
23			1.21	1.07						
24		1.11	1.09	1.05						
25			0.93	0.91						
26		1.31	1.21	1.11						
27		1.19	1.04	0.94	0.84					
28		1.35	1.23	1.12	1.04	0.97	0.90	0.84		
Monthly means		**1.20**	**1.11**	**1.05**	**0.90**	**0.87**	**(0.90)**	**(0.66)**	**(0.44)**	
Departure from 8-year normal		**−0.03**	**±0.00**	**+0.03**	**−0.03**	**−0.01**	**+0.03**	**−0.13**	**−0.32**	
P. M.										
Oct. 6		1.12	1.07	0.98	0.86	0.77	0.70	0.65	0.60	0.56
7		1.07	1.07	0.92	0.82	0.72	0.66	0.62	0.56	
8				0.84						
10		1.39	1.30	1.22	1.13	1.07	1.02	0.96	0.90	
11		1.24	1.07	0.96	0.86	0.79	0.72	0.65	0.58	
14		1.36	1.26	1.15	1.08	1.02	0.95	0.89	0.84	0.79
17		1.21	1.11	0.99	0.87	0.77	0.71	0.67	0.61	0.54
23		1.26	1.20	1.10	1.01	0.94	0.87	0.81	0.75	0.69
24			0.88				0.64	0.60	0.57	0.53
26			1.19	1.09	1.00	0.92	0.84	0.79	0.73	0.67
27			0.99	0.90	0.80	0.70	0.64	0.59	0.56	0.52
28			1.14	1.05	0.87	0.77				
Monthly means		**1.24**	**1.12**	**1.02**	**0.93**	**0.85**	**0.78**	**0.72**	**0.67**	**0.61**
Departure from 8-year normal		**±0.00**	**+0.01**	**±0.00**	**+0.02**	**+0.02**	**+0.01**	**+0.01**	**±0.00**	**−0.01**

Madison, Wis.

A. M.										
Oct. 3	1.18	1.05	0.95	0.86	0.78					
4	1.16	1.04	0.95	0.92	0.86	0.78				
6	1.35	1.28	1.20	1.13	1.07	1.01				
10	1.47	1.37	1.29	1.22	1.15	1.10	1.06			
13	1.44	1.31		1.17	1.09					
17	1.37	1.33	1.29	1.21						
27		1.33	1.25	1.19	1.09					
Monthly means		**1.33**	**1.24**	**1.16**	**1.10**	**1.01**	**0.96**	**(1.06)**		
Departure from 7-year normal		**+0.10**	**+0.10**	**+0.08**	**+0.09**	**+0.10**	**+0.12**	**+0.35**		

TABLE 1.—*Solar radiation intensities during October, 1916*—Continued.

Madison, Wis.—Continued.

Date.	Sun's zenith distance.									
	0.0°	48.3°	60.0°	66.5°	70.7°	73.6°	75.7°	77.4°	78.7°	79.8°
	Air mass.									
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	5.5
P. M.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.	Gr.-cal.
Oct. 3			1.09	1.02	0.95					
4			1.03	0.90	0.81	0.72				
6		1.23	1.19	1.01	0.96	0.91	0.87			
7		1.17	1.14							
10		1.46	1.35	1.26			1.07			
13			1.36	1.30	1.24	1.17	1.11	1.06	1.01	
17			1.35							
27					1.12	1.06				
Monthly means		**1.29**	**1.22**	**1.10**	**1.02**	**0.96**	**1.02**	**(1.06)**	**(1.01)**	
Departure from 7-year normal			**+0.07**	**+0.01**	**+0.03**	**−0.01**	**+0.08**	**+0.30**	**+0.37**	

Lincoln, Nebr.

A. M.										
Oct. 3		1.36	1.26	1.16	1.07	1.01	0.93	0.88	0.84	0.77
4		1.29	1.18	1.09	1.00	0.93	0.87	0.80	0.73	0.66
6		1.34								
10			1.33	1.22	0.97					
13		1.51	1.43	1.34	1.27	1.20	1.06	1.00	0.97	
17			1.37	1.29	1.16	1.08	1.02	0.95	0.91	
20			1.51	1.43	1.34	1.27	1.23	1.19	1.15	
25		1.56	1.48	1.41	1.33	1.26	1.19	1.13	1.09	
31			1.36	1.31	1.20	1.10	1.01			
Monthly means		**1.41**	**1.36**	**1.28**	**1.17**	**1.12**	**1.04**	**0.99**	**0.95**	**(0.72)**
Departure from 2-year normal		**+0.03**	**+0.04**	**+0.03**	**+0.01**	**+0.03**	**+0.03**	**+0.05**	**+0.05**	**±0.00**
P. M.										
Oct. 2		1.20	1.01	0.85	0.75	0.67	0.57	0.48	0.41	
3		1.30	1.12	1.02	0.94	0.87	0.80	0.73	0.69	0.66
4		1.24	1.06							
13			1.36	1.29	1.22	1.15	1.09	1.02	0.97	0.94
16		1.39	1.21	1.09	1.02	0.96	0.90	0.86	0.82	0.79
17		1.43	1.34	1.25	1.16	1.06	1.01	0.96	0.91	0.85
20		1.51	1.46	1.40	1.32	1.26	1.22	1.16	1.09	1.01
21		1.47	1.36	1.25	1.15	1.08	1.01	0.96	0.93	
26		1.40	1.26	1.17	1.09	1.01	0.97	0.93	0.89	
27		1.49	1.38	1.28	1.18	1.11	1.05	1.00	0.96	0.92
31			1.39	1.29	1.20	1.12	1.06	1.00	0.95	0.90
Monthly means		**1.38**	**1.27**	**1.19**	**1.10**	**1.03**	**0.97**	**0.91**	**0.86**	**0.87**
Departure from 2-year normal		**−0.01**	**+0.01**	**+0.02**	**±0.00**	**−0.01**	**−0.01**	**−0.01**	**−0.01**	**+0.01**

Santa Fe, N. M.

A. M.										
Oct. 2		1.43	1.35	1.29	1.24	1.18	1.13	1.08	1.02	0.98
3		1.53	1.46	1.38	1.31	1.25	1.20	1.14		
6			1.40							
16			1.39							
17		1.47	1.29	1.26	1.23	1.18	1.13	1.08	0.97	
18		1.44	1.35	1.21	1.13	1.11				
19		1.55	1.44	1.36	1.31	1.26	1.21	1.17	1.12	
20		1.56	1.48	1.41						
21		1.57	1.51	1.45	1.39	1.35	1.33	1.31	1.27	1.20
25		1.51	1.44	1.37		1.26				
26		1.57	1.51	1.43	1.37	1.31	1.25	1.21		
27					1.29	1.26	1.23	1.20	1.17	
28		1.53	1.47	1.42	1.36	1.31	1.27	1.23		
30		1.56	1.48	1.41	1.34	1.28	1.23	1.19	1.16	1.14
31		1.56	1.49	1.42	1.36	1.30	1.26	1.20		1.06
Monthly means		**1.52**	**1.43**	**1.37**	**1.30**	**1.25**	**1.22**	**1.18**	**1.12**	**1.10**
Departure from 4-year normal		**+0.05**	**+0.07**	**+0.06**	**+0.09**	**+0.10**	**+0.09**	**+0.04**	**+0.03**	
P. M.										
Oct. 2		1.51	1.37	1.30	1.24	1.19	1.13	1.08		
17		1.47	1.38	1.32	1.25	1.18	1.13	1.09		
19		1.57	1.48	1.40	1.31					
20		1.54	1.43	1.36	1.29	1.23	1.17	1.12		
25		1.51	1.44	1.36	1.28	1.20	1.16			
26		1.52	1.44	1.37	1.31	1.25	1.20	1.15		
28			1.43	1.34	1.25	1.18	1.15			
30			1.44	1.37	1.31	1.24	1.20	1.16		
Monthly means		**1.52**	**1.43**	**1.35**	**1.28**	**1.21**	**1.16**	**1.12**		

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.	Dates.	8 a. m.	8 p. m.
1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*
Oct. 1	4.37	6.27	Oct. 3	7.04	7.04	Oct. 2	2.62	10.97	Oct. 2	5.36	3.30
6	14.10	16.20	4	7.57	8.18	3	9.47	10.97	3	3.45	2.26
7	13.13	11.81	6	5.36	6.76	4	11.81	9.14	6	6.27	5.16
8	11.38	15.65	7	7.87	11.38	6	5.56	10.59	16	4.57	5.16
9	13.61	16.20	10	3.99	3.63	10	3.45	3.81	17	4.57	6.50
10	4.37	4.95	13	6.76	4.75	13	5.36	4.37	18	4.95	4.37
11	4.37	6.27	17	3.00	3.63	16	7.04	4.95	19	3.15	2.26
12	6.02	7.87	27	5.36	5.36	17	4.37	4.57	20	2.49	3.00
14	5.16	5.16	.....	.....	.....	20	1.60	2.87	21	2.87	3.15
17	13.61	5.16	.....	.....	.....	21	3.45	4.95	25	3.63	3.81
21	4.95	5.16	.....	.....	.....	25	4.37	5.16	26	3.15	3.81
23	4.75	5.79	.....	.....	.....	26	4.57	6.50	27	3.00	4.57
24	5.79	7.29	.....	.....	.....	27	4.57	7.29	28	4.75	2.62
25	5.79	9.47	.....	.....	.....	31	4.37	5.16	30	2.74	5.36
26	4.57	5.79	.....	.....	.....	.....	.....	.....	31	2.62	3.00
27	4.75	5.36	.....	.....	.....	.....	.....	.....	.....	.....	.....
28	5.56	6.02	.....	.....	.....	.....	.....	.....	.....	.....	.....

Table 3 shows about the normal amount of radiation for the month at Washington, a slight excess at Madison, and a deficiency of about 6 per cent at Lincoln.

TABLE 3.—*Daily totals and departures of solar and sky radiation during October, 1916.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
1916.	*Gr.-cal.*	*Gr. cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Oct. 1	470	399	226	125	115	−136	125	115	−136
2	364	378	394	23	97	35	148	212	−101
3	244	380	427	− 93	102	71	55	314	− 30
4	296	369	401	− 38	94	48	17	408	18
5	279	339	379	− 51	67	29	− 34	475	47
6	373	387	373	46	118	26	12	593	73
7	369	362	366	45	96	22	57	689	95
8	356	297	387	34	33	46	91	722	141
9	250	341	185	− 69	80	−153	22	802	− 12
10	467	396	399	151	138	64	173	940	52
11	396	329	191	83	74	−141	256	1,014	− 89
12	337	51	303	26	−202	− 26	282	812	−115
13	130	375	413	−178	125	87	104	937	− 28
14	404	322	334	99	75	11	203	1,012	− 17
15	234	182	80	− 68	− 62	−240	135	950	−257
16	108	284	363	−192	43	47	− 57	993	−210
17	332	351	393	35	112	80	− 22	1,105	−130
18	290	254	303	− 4	18	− 7	− 26	1,123	−137
19	90	203	126	−202	− 31	−181	−228	1,092	−318
20	211	33	434	− 78	−198	130	−306	894	−188
Decade departure							−479	−46	−240
21	368	162	365	82	− 66	65	−224	828	−123
22	297	112	289	13	−114	− 8	−211	714	−131
23	360	80	75	79	−143	−219	−132	571	−350
24	339	108	24	61	−112	−267	− 71	459	−617
25	287	64	369	11	−154	82	− 60	305	−535
26	354	182	330	80	− 33	46	20	272	−489
27	324	321	340	52	108	59	72	380	−430
28	324	151	172	54	− 60	−106	126	320	−536
29	289	38	287	22	−170	12	148	150	−524
30	160	273	173	−105	67	− 99	43	217	−623
31	208	270	307	− 55	66	38	− 12	283	−585
Decade departure							+294	−611	−397
Excess or deficiency since first of year:									
Gr.-cal.							−5,531	3,286	
Per cent							−4.7	+2.9	

If we extrapolate the radiation intensities obtained on the best days to air mass 1 (zenithal sun) and air mass zero (upper limit of the atmosphere) by the method illustrated in the REVIEW for September, 1915, **43**:441, fig. 1, and then employ the latter in connection with the vapor pressures given in Table 2 to compute the solar constant by the Smithsonian "Abridged procedure for determining approximately the value of the solar constant," [1] the values in Table 4 result. The values of the solar constant obtained from the measurements made at Madison, Lincoln, and Santa Fe, are in good accord. Those obtained from Washington observations are too low, as we might expect, since during the fall months the tendency must be for vapor pressure readings near sea level to give too low a value for the total vapor content of the atmosphere.

TABLE 4.—*Radiation intensities for zenithal sun, reduced to mean solar distance of the earth, and approximate values of the solar constant.*

[Gram-calories per minute per square centimeter of normal surface.]

Station.	Date.	Radiation intensity.		Solar constant.
		m=1	m=0	
	1916.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Washington, D. C.	Oct. 10, p. m.	1.49	1.71	1.84
	Oct. 26, a. m.	1.41	1.68	1.82
	Oct. 28, a. m.	1.43	1.69	1.83
Madison, Wis.	Oct. 10, a. m.	1.55	1.76	1.88
Lincoln, Nebr.	Oct. 3, a. m.	1.47	1.72	1.94
	Oct. 4, a. m.	1.40	1.66	1.88
	Oct. 13, a. m.	1.59	1.78	1.92
	Oct. 17, p. m.	1.53	1.76	1.89
	Oct. 25, a. m.	1.63	1.83	1.97
	Oct. 27, p. m.	1.58	1.83	1.99
	Oct. 31, p. m.	1.58	1.82	1.96
Mean				1.94
Santa Fe, N. Mex.	Oct. 3, a. m.	1.60	1.78	1.88
	Oct. 17, p. m.	1.54	1.71	1.85
	Oct. 19, p. m.	1.65	1.90	2.00
	Oct. 20, a. m.	1.63	1.80	1.90
	Oct. 25, p. m.	1.57	1.74	1.85
	Oct. 26, a. m.	1.63	1.78	1.89
	Oct. 26, p. m.	1.58	1.74	1.85
	Oct. 28, a. m.	1.57	1.70	1.83
	Oct. 30, a. m.	1.62	1.79	1.91
	Oct. 31, a. m.	1.61	1.76	1.86
Mean				1.88

Unusually high radiation intensities were measured at Lincoln, Nebr., on the morning of October 20, following a fall of about 4 inches of snow. By noon, however, the atmospheric transmission had diminished, so that the radiation intensity for air mass 1.5 had not increased over that obtained for air mass 2.0.

Skylight polarization measurements made at Washington on 14 days give a mean of 56 per cent and a maximum of 61 per cent on the 10th. This latter, which is 9 per cent less than the October maximum of 1915, is surprisingly low; since on several days, and notably on October 10, distant mountains could be seen with unusual clearness.

ADDITIONAL NOTE ON THE HIGH HAZE OF JULY AND AUGUST, 1916.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated: Washington, D. C., Dec. 4, 1916.]

In response to the request in connection with the note on "High Haze" in the August, 1916, REVIEW, **44**:433–434, the following description has been received from Mr. Cleve Hallenbeck, assistant observer, Weather Bureau, Roswell, N. Mex.

[1] Annals, Astrophysical Observatory of the Smithsonian Institution, Washington, 1908, **2**: 115.

THE HIGH HAZE OF AUGUST 2–4,1916, AT ROSWELL, N. MEX.

This haze was first observed during the forenoon of August 2. It grew denser as the day advanced, and was dense enough in the late afternoon to entirely obscure the sun 35 minutes before sunset. That it was a high haze is indicated by the fact that although it obscured the sun the few cumulus clouds in the sky were distinctly visible. The outlines of these clouds seemed to be slightly dimmed, but this may have been due to the hazy background. The haze was the densest I have ever observed, and the only one observed during five years in the semiarid West.

On the 3d and 4th the haze, while lighter, was still dense enough to obscure the higher clouds, if there were any. On each of the three days the sunlight had a noticeable red or orange effect, most noticeable, of course, on the 2d. Other than a dull red glow, there was no unusual display of sunrise or sunset colors.

Judging by the comments made by callers at the Weather Bureau office, each of whom had an explanation to offer on this phenomenon, it seems that haze is extremely rare in this section of the country.

As a possible explanation of this haze Riccò[1] communicates the following:

I wish to state that in July a strong outburst occurred of the Stromboli volcano, and that on July 4 there was an extraordinary eruption of fluid and incandescent lava to a great height, followed by a thick rain of lapilli and ashes. The emission of enormous columns of black cloud lasted many days.

Stromboli volcano is on a small island of that name in latitude 38° 50′ N., longitude 15° 10′ E.

Referring to my previous notes in the REVIEWS for July and August, 1916, **44**:382, 433–34, it will be seen that observations in the high Alps at an approximate latitude of 47° N., and longitude 8° E., show the presence of high haze about the middle of July.

In the United States, pyrheliometric observations show its presence at Washington, D. C., latitude 38° 54′ N., longitude 77° 03′ W., on July 29–30; at Madison, Wis., latitude 43° 05′ N., longitude 89° 23′ W., on July 27–29; and at Lincoln, Nebr., latitude 40° 49′ N., longitude 96° 45′ W., on July 29. At Santa Fe, N. Mex., during the third decade in July, the skies were too cloudy for pyrheliometric observations.

Furthermore, eye observations show that high haze prevailed at Roswell, N. Mex., latitude 33° 24′ N., longitude 104° 27′ W., on August 2–4, and there is evidence of its presence in southern California at both Mount Wilson and Los Angeles, latitude about 34° N., longitude about 118° W., during the latter part of July, although it did not reach its maximum intensity until early in August. Its presence at Mount Wilson is confirmed by spectro-bolometric measurements. It was also observed at the Lick Observatory, Mount Hamilton, Cal., latitude 37° 20′ N., longitude 121° 38′ W., during the first week in August, but no evidence of its presence was noticeable on Mount Rainier, Wash., latitude 47° N., longitude 122° W., between July 28 and August 4.

The brilliant twilight colors which accompanied the onset of this haze in California have continued up to November 1, although with diminishing intensity. Since August 1 pyrheliometric observations have given no indication of the presence of the dust, but at Washington a surprising decrease in skylight polarization has continued up to the 1st of December. Even on days when distant mountain ranges have stood out with unusual clearness the percentage of skylight polarization has been nearly 10 per cent less than has been measured on previous years under apparently similar atmospheric conditions.

In order that volcanic dust might reach southern California during the latter part of July, or 20 days after the violent eruption of Stromboli on July 4, an average wind movement from the east of about 7 meters per second, or 15 miles per hour is necessary; and to reach Washington, D. C., and Madison, Wis., by July 29, and Roswell, N. Mex., by August 2, a velocity of 4 meters per second, or 9 miles per hour, is necessary. If we suppose the movement to have been from west to east, velocities of 11.2 meters per second (25 mis. / hr.) must have been maintained. Our knowledge of upper air currents gained from recent balloon observations[2] assures us that such velocities are possible; but if the movement of the smoke cloud was by the shorter route, or from east to west, the volcanic explosion must have been of sufficient violence to project the dust to a height of at least 16 kilometers.

It is hoped that Professor Riccò has measurements which he will publish, showing the height of the smoke cloud at the time of the eruption; since if we attribute the high haze of 1916 to the eruption of Stromboli volcano on July 4, such measurements will give the observations here summarized considerable value in studies of atmospheric circulation.

[1] *Riccò, A.* Optical deterioration of the atmosphere and volcanic eruptions. Nature (London), Nov. 9, 1916, 98:190.

[2] *Blair, W. R.* Free-air data by means of sounding balloons, Fort Omaha, Nebr., July, 1914. MONTHLY WEATHER REVIEW, May, 1916, **44**:247–264.

SECTION II.—GENERAL METEOROLOGY.

ELEMENTARY NOTES ON LEAST SQUARES, THE THEORY OF STATISTICS AND CORRELATION, FOR METEOROLOGY AND AGRICULTURE.

By CHARLES FREDERICK MARVIN.

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Much attention is now being given by a few to the application of the laws of probabilities and of the theory of statistics, least squares, and correlation to studies in meteorology, especially in its relations to agriculture. These mathematical agencies may be made very useful to meteorologists and others in the analysis and comparison of the data of their respective sciences and in the determination of possible relations between the several phenomena or quantities they discuss.

The customary meteorological and climatic tables tell us a great deal about the mean temperature and average weather conditions of this or that locality and for the several days, months, seasons, etc. The departures from the normal, the extremes, and ranges of the conditions are also fully specified. Nevertheless, many realize how these data often fail to bring out climatic characteristics that impress themselves strongly upon our physiological or psychological sensations. A possible explanation of some of these anomalies may be found in recognizing that the *average* temperature, for example, or the *average* conditions of any kind are not necessarily the most frequent or the most probable conditions. The average or the mean *may* be the most frequent in *some* localities or at certain times and seasons, whereas it is entirely possible and in fact quite probable that in another locality or on another occasion the most frequent temperature may be either above or below the mean or normal.

The *standard deviation* is another mathematical concept that may be employed to express a characteristic or peculiarity of a given climate and likewise claims attention. Different localities and different elements may show marked differences in these characteristics and such differences can not fail to be accompanied by psychic and physiological effects on man and by corresponding effects on other organisms. All these climatic features and peculiarities can be fully disclosed only by a proper application of the laws of statistics to the several problems in hand. Vast quantities of suitable data are already available and await analysis and discussion of the kind indicated.

Many interesting questions may be answered with assurance by means of the mathematical methods referred to; for example:

1. In the long run, how many days in December at Washington, for example, will the minimum temperature fall below freezing?

[Some will be content to count up the times for a series of years. A far better result may be obtained, however, by a proper application of the theories of statistics.]

2. What will be the most frequent temperature at a given locality and for a specified interval of time?

3. Below what temperature will the minimum for the day at a designated place and period of time be just as likely to fall as not?

4. How many times in a month will the temperature be the same as the average?

5. What percentage of maximum temperatures for a given month and locality will be 10°, 15°, or 20° above the normal?

6. How do different localities differ in one or more of the particulars indicated in the foregoing questions?

7. Are differences in the particulars cited reflected in the growth of crops or the welfare and comfort of individuals, and, if so, what are the economic and hygienic aspects thereof?

Weather conditions rainfall, river stages, crop yields, and many other important phenomena of meteorology and agriculture can be analyzed and set forth with advantage by the mathematical methods indicated.

Prof. Karl Pearson, of University College, London, has done much to systematize and reduce to a practical working basis the intricate mathematical processes that must be employed in order to reach exact and rational results in the discussion of large groups of statistical data. His important contributions to this science should be consulted by every careful student.

Except for the safe and certain basis afforded by the science of statistics for the risks of insurance, for example, this great industry in all its manifold applications of the present day would be either a costly investment to the policyholder, or a losing venture to the company, and not the perfectly safe and equitable business enterprise it now is.

Biologists, anthropologists, and other students of statistics generally now employ the exact mathematical methods of this comparatively new science with great advantage in their several fields of work. A few meteorologists must also be mentioned in this list, but as yet little has been done, especially in American climatology and agriculture,[1] to use this science to the fullest possible extent in solving many of the practical problems of applied meteorology and scientific agriculture.

[1] Prof. W. J. Spillman has recently made important practical applications of statistical theories to the problems of farm management as dependent on weather factors. His assistants, Messrs. W. G. Reed and H. R. Tolley, are also making investigations of climatic and agricultural statistics from the mathematical standpoint, and useful results may be expected. *See* MONTHLY WEATHER REVIEW, April, 1916, 44: 197; June, 1916, 44: 354.

Many who are interested or engaged in the study of the data of weather, climate, and crops are but slightly acquainted with advanced mathematics. Such are frequently dismayed by the formidable array of mathematical symbols commonly employed to demonstrate the theories of errors or variations and fail to follow and learn the methods and processes by which these theories may be applied in the solution of many practical problems. Hence, it seems a useful purpose will be served by stating in simple verbal terms, as far as possible, some of the generalizations warranted by the more elegant mathematical demonstrations and by illustrative examples of the processes of computation indicated by the equations of this branch of science.

With this object in view it is proposed to discuss briefly several of the more or less technical terms now in use and illustrate by simple examples certain important methods of computing results.

EXPLANATION OF TERMS.

Average, mean, normal.—Mathematically, the quantities to which these names are applied in dealing with statistical data are essentially the same, namely, the quotient found by dividing the sum of a series of values by the number of values. In ordinary usage there is no essential difference in the significance of average and mean, although the latter sometimes means the value midway between two extremes, whereas the average has only the mathematical significance of the sum of the observations divided by the number. The word *normal*, however, as used in meteorology, is supposed to have a special significance, which can not be more precisely defined than to say that it is the average value of a long series of observations. Just how long the series must be to make the average a real normal can not be known, except possibly to say that the average becomes the normal when its value ceases to change appreciably with increased length of record. This is altogether a question of the importance or significance of small changes in the value of the average. Notwithstanding its vagueness of meaning the word *normal* is a convenient one to distinguish the average of a few results from the mean of a considerable number, or even the greatest number of values available.[2]

Errors, residuals, departures.—These terms often have a similar significance, but in other cases important differences of meaning must be recognized. All measurements and observations of physical magnitudes, as also the observation and determination of the elemental terms constituting statistical data, show variations when more than one observation or determination are made. In general it is impossible to learn the true magnitude. When used in its strictest sense, the word *error* means the difference between some particular observed value and the true value of a datum. Since the true value, and therefore the true error, can perhaps never be known, it is customary to adopt in place of the true value some closely approximate, or best, or most probable value. Careful writers will then use the word *residual* to mean the difference between some particular observed value and the most probable value. The word *error*, however, is often loosely used to have the same significance as *residual*.[3]

Errors and residuals may be considered as variations of repeated observations or measurements, from the true or the approximate value of a given magnitude *which in effect is assumed to remain fixed and invariable*. While the determination of each element of statistical data—*e. g.*, the velocity of the wind, the temperature of the air, the amount of rainfall, etc.—is, strictly, subject to errors of observation, nevertheless such data are also subject to an additional cause of variation due to the progressive and actual change in the true value of the wind velocity, the temperature of the air, the rainfall, etc. In such cases the *errors* of determination can not as a rule be eliminated or separately analyzed, but they are generally small and insignificant in comparison with the larger variations of the elemental datum itself.

The term *departure* may be reserved to designate the difference between the mean value and some one of the values of a quantity *which is more or less continuously changing its magnitude*. It is not at all necessary, however, to form the departures with respect to the mean. Indeed, it is generally easier and better to use some arbitrary value, as the computations can thus be carried out with greater facility and even more exactly. (See p. 563.)

Errors and *residuals* represent inexactness and imperfection in determining quantities of a fixed magnitude. Departures show the nature and amount of variations in a quantity of changing magnitude.

Correction.—The numerical value of a correction in a given case is always exactly the same as that of an error or residual, or departure, but it has the opposite algebraic sign. It is the quantity that must be added algebraically to an *observed value* to deduce thereby the *true* or *most probable* value. The word has no particular use in the study of statistical data, but is explained here to bring out the difference between *corrections* which are very frequently employed in adjusting observations, measurements, and data generally and the *variations* or *departures* which constitute the ground work of statistics.

Deviation is a word which is also used to refer to the amount of departure from a mean or arbitrary base value.

Standard deviation is the name applied to a particular value of the departures in a group of data and is extensively employed in statistics as an index of the variability of the group and for other purposes. Its importance or usefulness depends chiefly upon its mathematical significance, as will be brought out more fully in what follows.

Probability curve.—A curve of the general character shown in figure 1 and representing the law of frequency with which errors or residuals of different magnitude occur. The height of any point on the curve above the base line is proportional to the number of errors or residuals which have the value represented by the distance of the point from the vertical axis of symmetry. *Normal distribution, normal curve of errors* are other names applied to the probability curve.

Frequency curve.—A curve exhibiting the law of frequency of occurrence of departures of various magnitudes from a base or reference number. The curve may be identical in character with the probability curve, but unsymmetrical curves of various kinds may also be required to exhibit particular kinds of data, as will be indicated later.

Distribution, frequency distribution.—Expressions referring to the grouping of departures as exhibited by a frequency curve or diagram. An easy and expeditious manner of charting a frequency distribution is the dot system shown in figures 15 and 16. When the departures have been calculated the dot chart can be rapidly built up and the result is graphic and effective. In fact, the

[2] On this subject of "mean" and "average" see also this REVIEW, Jan., 1915, 43: 24; Aug., 1895, 23: 294.—C. A. jr.
[3] *Merriman, M.* Method of least squares. New York, 1915. p. 5.

chart is often just as easily formed directly from the observations, thus reducing to a minimum the labor of computing and tabulating numerical departures.

Least squares, sum of squares.—These expressions refer to the sum of the squares of the errors, or residuals, or departures for a given group of data. The magnitude of the sum will depend on the base number with reference to which the departures are taken. Some one base number will cause the sum of the squares to be a minimum, hence the expression "least squares." When the data represent physical measurements, that value which makes the sum of squares the least is the most probable value and therefore the most accurate value obtainable from the data discussed. The arithmetical mean is the most probable value in the case of observations of equal accuracy.

In dealing with statistical data the most probable value does not have the significance of the most *accurate* value, but simply is the most *frequent* value. If the "distribution" is unsymmetrical the arithmetical mean will then no longer be the most frequent value, but some other value will be the most frequent. The name *mode* is now used to designate the most frequent value.

Probable error, probable variation.—These expressions are mathematically identical, at least when the "distribution" is normal, nevertheless there is clearly an appropriate distinction between them. The probable error has reference to a group of measurements *of a fixed quantity* and designates that error than which half of the errors are greater and the remaining half are less. The *probable variation* refers to the changing values of a *variable quantity* and is the name of that magnitude of the departure which has the middle value, that is, half of the deviations in a given group of data are greater, and half are less, than the probable variation.

Variant.—This term is frequently used to designate in a general way any group of data exhibiting variation. In meteorology, for example, the rainfall for a given period and locality might be referred to as *the variant*, and a given single value as *a variant*.

ELEMENTS OF THE LAWS OF PROBABILITY.

Let m = number of ways in which a certain simple event can happen,

n = number of ways in which the event can fail,

then

$m+n$ = total number of cases that can occur.

If the probability that the event will happen be called p, then

$$p=\frac{m}{m+n}.$$

If $n=0$, $p=\frac{m}{m}=1$, that is, it is certain the event will happen since 1 is the measure of certainty.

If $m=0$, $p=\frac{0}{n}=0$; that is, it is certain the event will fail, zero being the measure of complete failure.

If a compound event occurs when two or more simple events happen together, then the probability of the compound event is the product of the probabilities of the simple events.

THE THEORY OF ERRORS AND THE METHODS OF LEAST SQUARES.

These expressions designate a group of theories and mathematical methods based on the laws of probabilities, all originally developed chiefly by astronomers, mathematicians, and geodesists for the purpose of providing rational methods of comparing, adjusting, combining, and harmonizing many different measurements or observations of one and the same quantity so as finally to ascertain the best, or the most accurate, that is, the most probable value that could be deduced from all the observations.

This theory, however, has a far wider application than simply to errors of measurement. In meteorology and climatology it may be a valuable mathematical agency for indicating the nature and amount of *variation* in the data commonly discussed.

The theory of errors, in fact, deals with only one of the special and relatively simple cases that fall within the domain of the more general theories embracing all classes of statistical data subject to variations. *The theory of statistics* is the general science. The *theory of errors* is the special case. Care must be exercised, therefore, that formulæ and methods appropriate for the analysis and discussion of errors of measurements are not applied to data whose laws of frequency and variation may be quite different from those upon which the theory of errors is constructed.

It is also well known that the theory of errors—or "of departures from a mean" as the theory might be called for meteorologists—applies strictly only to a very large number of observations or values. The smaller the number of cases the less reliable are the deductions by this theory. As already stated, the principles of the theory were formulated with respect to errors of measurements and observations; nevertheless, under proper restriction they may also be applied to many studies and discussions of statistical data generally. In these latter cases the question at issue is not one of *errors of observation*, in the proper sense of that expression. Meteorological observations and statistical data generally are all subject to errors of determination or measurement, and it is often impossible to adequately eliminate these causes of variations from the results under discussion. Nevertheless the pure errors of observation will often be small and in the application of the theories now under consideration the "*residuals*" will be *departures* from a mean value or arbitrary base number and not errors of determination. The departures represent chiefly the *variations* in the values of a given datum with respect to some average or mean value that it may be convenient to employ as an arbitary reference value, but includes nevertheless the actual errors of observation.

Take, for example, the mean temperature of January, or any other month for a long series of years, or, better the mean temperature for any day of the year. This datum tends to be a constant; nevertheless, values from year to year differ more or less from the mean, sometimes higher, sometimes lower. Some months or days and some localities show greater variations than other months and other localities. This variation is a more or less fixed characteristic of the given month or of the locality and some standard method of generally measuring and designating such variations is needed. The method of least squares supplies such a standard method or unit of measurement of variation. This unit is known as the probable error or, giving it a more appropriate name, the *probable variation*. The term *standard deviation* is also a name for another measure of this variation that serves to define in exact measure the variation of similar climatic, meteorological, or statistical data to which the methods of least squares may be applied. These terms will be described and defined more fully hereafter.

At the very outset of any general attempt to apply the methods of least squares to some particular data other

than to questions involving only errors of observation, it is highly important to make sure that the theory can properly be applied to the particular data in question and in the manner proposed. Whether this application can be made or not depends on whether the law of the *requency* of occurrence of the large and the small deviations from the mean in the data is the same general law as for errors of observations. That is, the extent to which this application is justified depends on how closely the so-called frequency curve for the data in question corresponds to the frequency curve for errors of observations. We must therefore recognize just what are the characteristics and limitations of the normal curve.

Normal frequency curve.

The essential features of the law of frequency of occurrence of errors is represented by what is often called the "normal frequency curve." This law of frequency is fixed by three principal conditions which must be satisfied, namely, (1) very small errors occur with the greatest frequency; (2) very large errors rarely occur; (3) positive errors (values of the data in excess of the true value) and negative errors (values less than the true value) are equally numerous. This latter condition makes the frequency curve symmetrical about the central vertical axis.

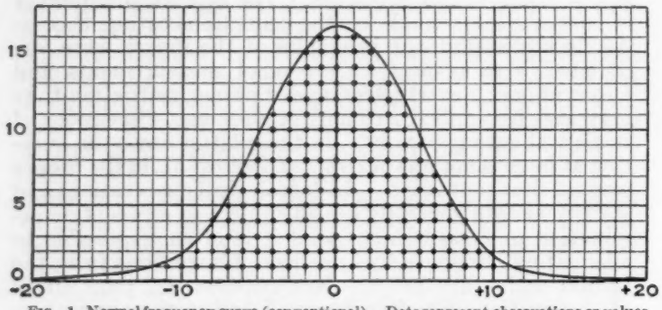

FIG. 1. Normal frequency curve (conventional). Dots represent observations or values assumed to be very numerous and crowded close together.

Figure 1 represents a normal frequency curve having these characteristics. Each dot may be considered to represent one observation or one value of the departure from the mean, the amount of that departure being shown by the distance of the dot from the central line. All the dots comprise all the observations.

Scientists have determined that the normal probability curve of the kind shown in figure 1 is best represented by a certain exponential equation which written in a form commonly found in the textbooks [4] is as follows:

$$y = \frac{h}{\sqrt{\pi}} e^{-h^2x^2} \qquad (1)$$

in which y represents the probability of a given value or deviation from the mean represented by x. The quantities π and e are well-known mathematical constants, namely, $\pi = 3.1416$, the ratio of the circumference to the diameter of circles and $e = 2.71828$, the base of the Naperian system of logarithms. These quantities are the same for all kinds of data whatsoever. The one remaining factor h is a constant depending on the particular data under discussion. This quantity h is sometimes called "the measure of precision."

When h is small the curve is low and spreads out laterally as a or b in figure 7. For such a case the observations are inexact or the data vary greatly, and relatively large departures from the mean occur frequently. Such data lack precision and exhibit wide variations. A large value of h, however, signifies that the measurements or data are grouped closely about the mean value, small deviations are numerous and large ones seldom occur. The curve in this case will have such a form as shown at c or d in figure 7.

According to equation (1) the frequency curve has branches on the right and left extending to infinity, but errors or departures even approaching infinite magnitude do not occur. Hence we must recognize that equation (1) only approximately represents the real case in nature. Nevertheless, the mathematical curve can be made to lie so close to the base line as to practically coincide with it at the limits of the range of data.

It was mentioned with respect to figure 1 that all the dots comprise all the observations. In an analogous but more generalized sense the entire *area* under the curve including its branches to infinity, represents all possible errors; and the area under the curve between any two defining vertical lines in proportion to the whole area represents the probability of the occurrence of errors of sizes between the defining lines.

When we undertake to study the variation of statistical data generally, it is quite obvious we must expect to find frequency curves widely different from the normal error curve. Pearson and others have classified many of these curves and determined their general equations. A few extreme types are selected here to illustrate the possibilities and are shown in figures 2–8.

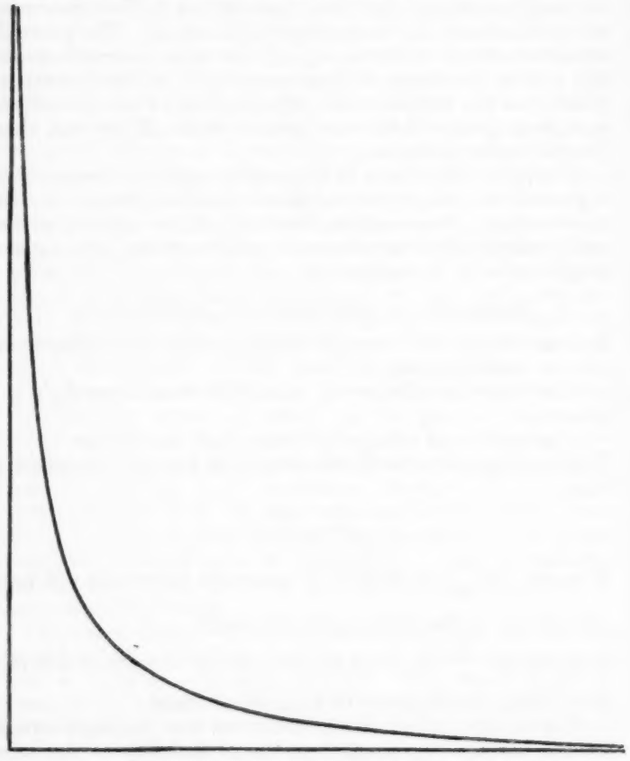

FIG. 2. Extreme asymmetrical frequency curve. Illustrates frequency of deaths from infantile diseases.

Figure 2 shows the extreme asymmetrical [5] type illustrating, for example, the frequency of deaths at different

[4] *Comstock, George C.* Methods of least squares. Boston, 1889?, p. 5.

[5] Unfortunately the designation "asymmetrical" is frequently applied by high authorities to curves which are but slightly unsymmetrical. Clearness of expression and consistency seem to justify restricting the use of "asymmetrical" to cases of total absence of symmetry, analogously with the application of "aperiodic" to motions of harmonic character but devoid of period. The word "unsymmetrical" may then be employed to designate frequency curves that are neither perfectly symmetrical, as in the case of the normal curve of errors, nor yet completely devoid of symmetry as in the case of the truly asymmetrical curve.

ages for certain infantile and children's diseases, like diphtheria, etc. A curve of this type shows also the distribution of wealth.

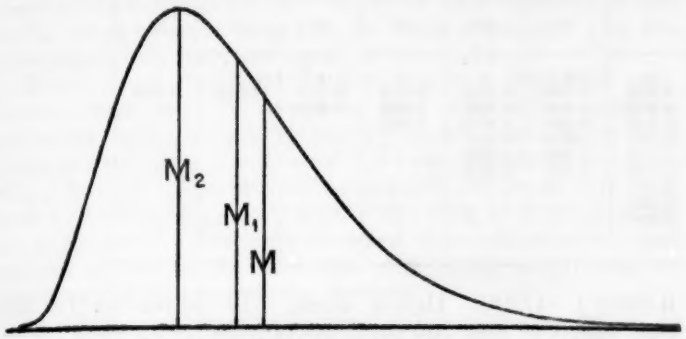

FIG. 3. Unsymmetrical frequency curve.
M_1=The mean or average value.
M_2=The median or value of middle magnitude.
M_3=The Mode, the most frequent value.

Figure 3 shows an unsymmetrical[5] curve representing many classes of data, exhibiting varying degrees of asymmetry. Such curves may be classified into several distinct types according to significant mathematical criteria distinguishing between their equations.

Skewness is another term employed to indicate lack of symmetry in a frequency distribution.

Some kinds of data are most conveniently analyzed in classes or subgroups. For example, the different amounts of rainfall at a station may be shown in half-inch groups. In such cases a frequency diagram like figure 4 is called a *frequency polygon*. In these cases the frequencies are imagined to be concentrated on the central ordinates of the successive groups, and this method is frequently spoken of as the method of loaded ordinates. Another illustration of a diagram of this character is found in figure 18. The same data may be represented also by a system of rectangles like figure 5, which is sometimes called a histogram.

FIG. 4. A frequency polygon exhibiting the irregularities of actual data.

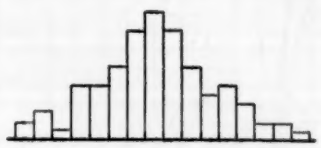

FIG. 5. A frequency diagram outlined by rectangles sometimes called a histogram.

Figure 6 is an unusual type of frequency curve drawn from climatic data and showing the frequency of estimated cloudiness at Breslau[6] during the 10 years 1876–1885. A completely clouded sky is the most frequent condition, while a perfectly clear sky is the condition next in order of frequency. Intermediate percentages of cloudiness are more rare.

Properties of the probability curve.—The normal error curve has a number of interesting properties, some of which will be briefly considered.

The fundamental equation of the curve is

$$y=\frac{h}{\sqrt{\pi}}e^{-h^2x^2} \qquad (1)$$

[5] *Yule, G. Udny.* An introduction to the theory of statistics. London, 1912, p. 103.

Since π and e have the same values for all kinds of data, and since we may, if we desire, use the same scale for x in representing different classes of data, it results that a family of curves such as shown in figure 7 suffices to represent every possible group of data that can be represented by the normal frequency distribution. Each curve represents a given group of data with a corresponding value of h.

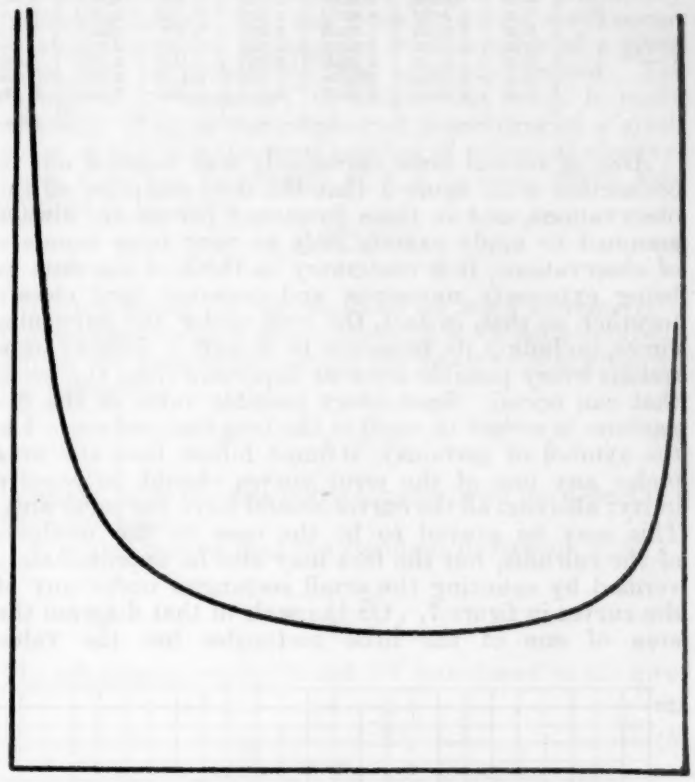

FIG. 6. Unusual frequency-curve representing cloudiness.

The curves in figure 7 were drawn from the data in Table 1, below, giving values of y for a series of values of x in equation (1) and various values of h. The logarithmic form of equation (1) is employed for easy computations, thus:

$$y=\frac{h}{\sqrt{\pi}}e^{-h^2x^2} \qquad \text{or } \log y=\log\frac{h}{\sqrt{\pi}}-h^2x^2\log e.$$

Putting $\log\frac{h}{\sqrt{\pi}}=a$ and $h^2\log e=b$, we get the simple equation

$$\log y=a-bx^2 \qquad (1a)$$

If a calculating machine of the "Brunsviga" type is available, values of the second member of the equation may be rapidly computed by first setting up a in the product roll, then b in the number roll; finally the successive substraction of bx^2 from a by properly operating the machine for successive values of x, gives values of $\log y$ directly in one operation.

TABLE 1.—*Values of* a, b, *and* y, *for values of* x *and different values of* h, *computed by equation (1a).*

h	a	b	x										
			0	2	4	5	6	8	10	15	20	25	30
			y	y	y	y	y	y	y	y	y	y	y
0.05	8.45040	0.00108	0.0282	0.0279	0.0271	0.0265	0.0258	0.0240	0.0220	0.0161	0.0104	0.0059	0.0030
0.10	8.75142	0.00434	0.0564	0.0542	0.0481	0.0439	0.0394	0.0298	0.0208	0.0059	0.0010	.....	.....
0.15	8.92752	0.00977	0.0846	0.0773	0.0590	0.0482	0.0376	0.0200	0.0089	0.0005	.....	.....	.....
0.20	9.05246	0.01737	0.1128	0.0962	0.0595	0.0415	0.0267	0.0087	0.0021	.....	.....	.....	.....
0.25	9.14937	0.02714	0.1410	0.1098	0.0518	0.0296	0.0149	0.0026	0.0003	.....	.....	.....	.....
0.30	9.22855	0.03909	0.1693	0.1181	0.0401	0.0178	0.0066	0.0005	0.0000	.....	.....	.....	.....
0.35	9.29550	0.05320	0.1975	0.1210	0.0278	0.0092	0.0024	.....	.....	.....	.....	.....	.....
0.40	9.35349	0.06949	0.2257	0.1190	0.0174	0.0041	0.0007	.....	.....	.....	.....	.....	.....
0.45	9.40464	0.08794	0.2539	0.1129	0.0099	0.0016	0.0002	.....	.....	.....	.....	.....	.....
0.50	9.45040	0.10857	0.2821	0.1038	0.0052	0.0005	.....	.....	.....	.....	.....	.....	.....

Area of normal error curves.—It was pointed out in connection with figure 1 that the dots comprise all the observations, and as these frequency curves are always assumed to apply exactly only to very large numbers of observations, it is customary to think of the dots as being extremely numerous and crowded very closely together, so that, in fact, the *area* under any particular curve, including its branches to + and − infinity, represents every possible error or departure from the mean that can occur. Since every possible value of the departures is *certain* to occur in the long run, and since 1 is the symbol of certainty, it must follow that the area under any one of the error curves should be exactly unity; also that all the curves should have the same area. This may be proved to be the case by the methods of the calculus, but the fact may also be approximately verified by counting the small rectangles under any of the curves in figure 7. On the scale of that diagram the area of one of the little rectangles has the value $0.005 \times 1 = 1/200$. Hence there will prove to be the equivalent of just 200 small rectangles under each curve.

Since the area of a curve represents the probability of all possible departures, so likewise the fractional area between ordinates represents the probability of departures lying between the limiting ordinates.

The probable error.

Mention has already been made that h in equation (1) is called the measure of precision. Its use, however, for this purpose seems to be confined almost exclusively to abstract mathematical discussions of equations of probability. Astronomers, physicists, and others engaged in precise measurements almost universally employ the *probable error* as a measure of precision or index of variability of their work.

The probable error or *probable variation* is that value of the departure that is just as likely to be exceeded

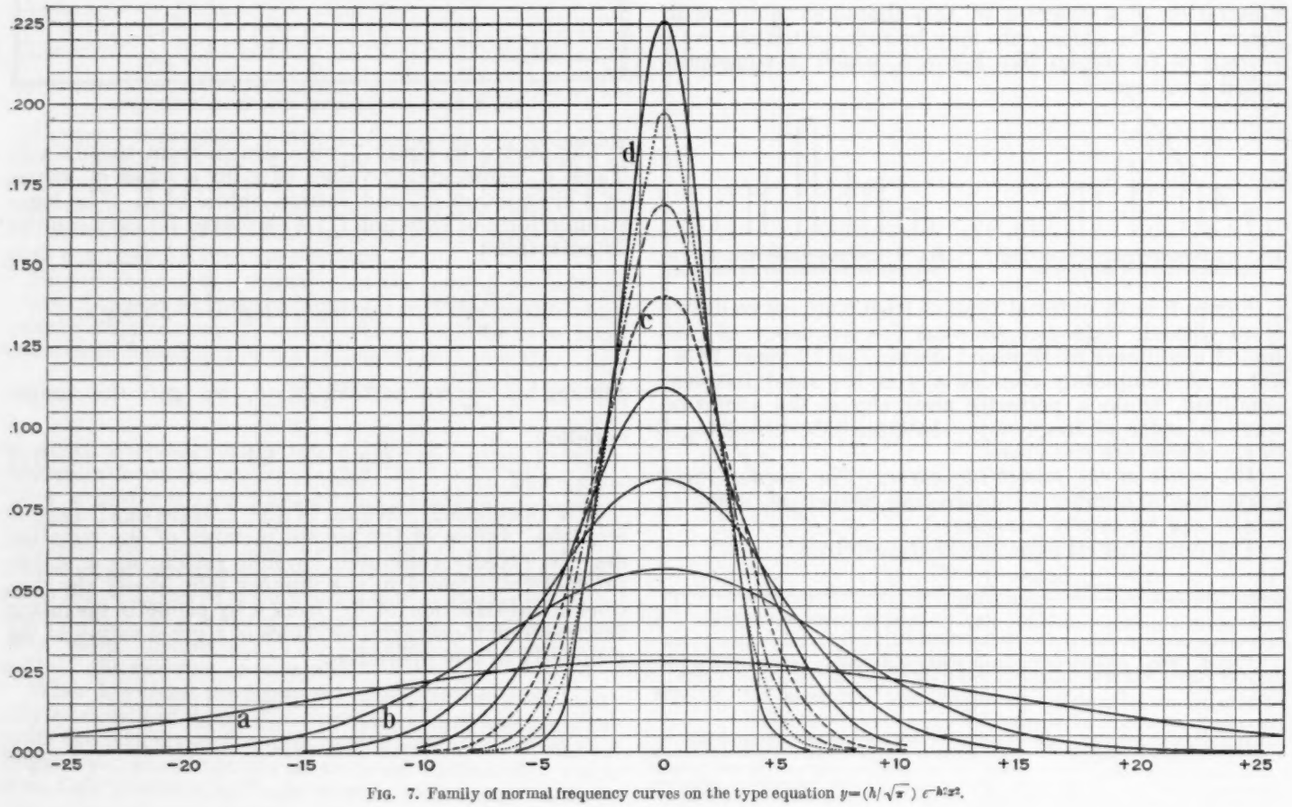

FIG. 7. Family of normal frequency curves on the type equation $y = (h/\sqrt{\pi})\, e^{-h^2x^2}$.

as not. It bears the same relations to the other errors that the *median* does to the original data; but the probable variation must not be confused with the median, as the two are wholly different. Half of the departures are equal to or greater than the probable departure and the remaining half have an equal or less value.

Every frequency distribution has two probable variations—one with a positive and the other with a negative sign. If the frequency distribution is normal then the numerical values of the two probable variations are identical. The probable variation ordinates $+E, -E$, in a frequency diagram, divide the area into three parts as in figure 8. The area between the ordinates is equal to half of the whole area and also equal to the sum of the areas of the remaining portions.

In skew or unsymmetrical distributions the probable variation as a value loses the significance assigned to it just above. In such a case the probable variation is simply the probable variation of a normal error curve of best fit to the particular group of skew data.

The probable variation is a measure of the amount of variation or disagreement in the values under discussion. When applied to measurements it is an index of accuracy. The smaller the probable error the greater the accuracy. When applied to data, the smaller the probable variation the smaller the dispersion or variation of the data from the mean.

Authorities give slightly different formulæ for computing the probable variation or probable error. *E. Hooker* (Quart. Jour., Roy. Met. Soc., 1908, **34**: 281) gives the value of the probable variation as two-thirds the standard deviation. *Yule* (Theory of Statistics, pp. 306–307) places the value of the probable error at

$$E=0.6745\sigma=0.6745\sqrt{\frac{\Sigma x^2}{n}}$$

Davenport (Statistical Methods, 1915, p. 15) gives essentially the same value.

These formulæ may properly be applied when a large number of observations, n, is available; but the result is inaccurate for small values of n because the formula is deduced under mathematical assumptions that Σx^2 represents the sum of squares for a large number of variations. When these requirements can not be regarded as satisfied, it is customary to use the following formula:

$$E=0.6745\sqrt{\frac{\Sigma x^2}{n-1}}$$

(*See* Merriman: Method of least squares, 1915, p. 70.)

Astronomers, physicists, and others engaged in accurate measurements use the probable error frequently. Statisticians, however, and others engaged in like studies rarely use either the probable variation or the measure of precision as an index of variability, but employ a still different measure to indicate the characteristic deviations or dispersion of any given data. This measure is called the "standard deviation."

The standard deviation.

Those values of the departure which locate the points on a frequency curve where the curvature changes from convex to concave, that is, points of inflection, are values of the *standard deviation*. Like the probable variation, the standard deviation has positive and negative values which are numerically equal for *normal* distribution. The Greek letter small sigma (σ) is commonly employed to indicate standard deviation. When the standard deviation is computed for an unsymmetrical distribution of data, its significance is only that of the standard deviation for the normal error curve of closest fit to the particular data. *See* $+\sigma$ and $-\sigma$ in figure 8.

The facility with which values of the standard deviation may be computed for a given set of data makes it a very convenient measure or index of variability and partly explains its adoption for this purpose.

Evaluation of h.—In equation (1) y is the probability (certainty being 1) that any given departure x will occur. In statistical work the *number* of departures of a given value, not its probability, are generally desired. The change in (1) necessary to obtain this result is easily effected. If y_n is the number of departures of a given value, x, and n is the total number of values or observations, then the probability of x is $y_n/n=y$, which substituted in (1) gives

$$y_n=\frac{nh}{\sqrt{\pi}}e^{-h^2x^2}. \tag{2}$$

In textbooks on the methods of least squares it is proved that for any given group of n variants conforming to the normal frequency, the value of h is given by the expression

$$h=\sqrt{\frac{n}{2\Sigma x^2}}, \tag{3}$$

in which Σx^2 is the sum of the squares of all the departures from the mean.

It is also proven that the standard deviation, σ, is

$$\sigma=\sqrt{\frac{\Sigma x^2}{n}}. \tag{4}$$

The relations given in (3) and (4) introduced in (2) give:

$$y_n=\frac{n}{\sigma\sqrt{2\pi}}e^{-\frac{x^2}{2\sigma^2}} \tag{5}$$

This form of the equation in units of the standard deviation is the one commonly employed in statistical studies.

A still further simplification of the equation may be made. The expression $\frac{n}{\sigma\sqrt{2\pi}}$ is the value of the maximum ordinate, y_0, that is, the value of y_n when $x=0$.

Let

$$y_0=\frac{n}{\sigma\sqrt{2\pi}} \text{ and also let } X^2=\frac{x^2}{\sigma^2},$$

then substituting these values in equation (5), the latter may be written

$$y_n/y_0=Y=e^{-\frac{1}{2}X^2}.$$

This is the completely generalized equation of the normal frequency curve. The ordinates, Y, are measured in units of the maximum ordinate and the departures or abscissæ, X, are measured in units of the standard deviation. In this form the equation is applicable to every possible group of data conforming to the normal distribution. The logarithmic form of the equation is

$$\log\ Y=-\frac{\log e}{2}X^2=-0.217145X^2.$$

Adding and subtracting 10 to the second member gives

$$\log\ Y=10-0.217145X^2-10, \tag{6}$$

which puts the value of log Y derived from the equation

in the form in which logarithms are commonly tabulated. Figure 8 is the graphic representation of the equation (6).

Tables [6] of values of Y obtained by this equation are to be found in many of the standard works on least squares, etc.

When $X=5$, Y is less than one part in 100,000. While the lateral branches of the curve extend to $\pm\infty$, the actual extension beyond $X=\pm 5$ is therefore almost inappreciable.

The following values serve to plot the curve shown in figure 8.

X.	0	.2	.4	.5	1.0	1.5	2.0	3.0	4.0	5.0
Y.	1.00000	0.98020	0.92312	0.88250	0.60653	0.32465	0.13534	0.01111	0.00034	0.00000

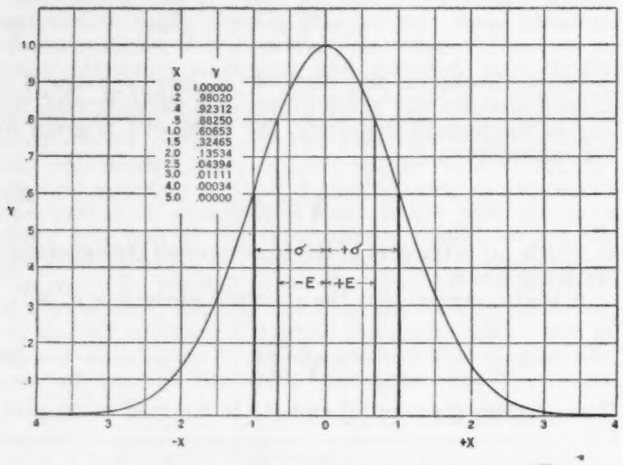

FIG. 8. Completely generalized normal frequency curve, $Y=e^{-\frac{1}{2}X^2}$.

The probability integral.—The methods of calculus provide means for evaluating the area of the generalized probability curve and tables of this area, otherwise known as the probability integral, have been prepared. Such tables [6] in conjunction with tables of Y mentioned in the preceding paragraph are of great service in answering many important questions in probabilities.

Most probable departure; the mode.—In any frequency distribution that value of the varient which occurs most frequently is commonly called *the mode* (cf. the fashion). In the *normal* distribution, a zero departure is the most frequent, consequently the average value is the most frequent value. In the case of so-called skew variations or unsymmetrical frequency curves, however, the mode and the arithmetical mean differ more or less.

The median.—This name is applied to the middle value of a series of variants when arranged in order of their magnitude. Half of the values of the variant are equal to or greater and the remaining half are equal to or less than the median. In data conforming to the *normal* distribution the mean, the mode, and the median all have the same value. In the case of skew variations the three values differ more or less as indicated in figure 3 and the median in such cases always lies between the mean and the mode. According to Pearson [7] the median is roughly one-third of the distance from the mean to the mode as measured on the axis of X.

[6] *Davenport, C. B.* Statistical Methods, 1914. Tables III and IV.
Sheppard, W. F. New tables on the probability integral. Biom., Feb. 1903, 2: 174.
[7] *Pearson, K.* Variation of the egg of the sparrow. . . . Biometrika, I, January, p. 261.

PROCEDURE IN STATISTICAL STUDIES.

Data undergoing study and investigation should first be plotted, if possible, upon some appropriate system of coordinates. Plotting should be recognized as an indispensable step in the search for relations between observed phenomena supposed to be dependent on each other or similarly influenced by a third condition. The degree of interdependence, as well as the character of the relation (as mathematically defined), is indicated by the consistency with which the plotted data aligns itself to some recognized mathematical line or curve. Students are often content to stop when a smoothed, hand-drawn curve has been constructed to represent results, and often our meager knowledge of the problem affords no other course. In many cases, however, the mathematical law of relation is fully known, as well illustrated by the normal frequency curve, for example. In all such cases the work should not be regarded as finished until the *equation* of the best fitting line or curve has been evaluated. Such a mathematical curve is far superior to the smoothed, hand-drawn curve, for which the student has no better guide than the limited and probably imperfect data before him. The mathematical curve not only fits all the data the best possible, but defines the general law to which the observations are believed to conform more and more closely as their number and accuracy increases.

Moments of curves.—The mathematicians have borrowed from the physicists and have applied to the solution of statistical problems the idea of moments taken from mechanics in which the product of a given quantity (usually a force) by a distance from an axis or origin is called a moment. The *first moment*, commonly designated, ν_1, of a group of statistical data comprising n values is in reality simply the algebraic sum of all the departures from the mean or some convenient reference value, *divided by* n; the *second moment*, ν_2, is the sum of the squares of the same departures *divided by* n; the *third moment*, ν_3, is the sum of the *cubes divided by* n, and so on. Stated in this form the idea of moments as a product does not seem to enter. If, however, f, is the frequency, that is the number of departures, all of the same value x, then fx represents the sum of those departures and $\frac{\Sigma fx}{n}=\nu_1$ is the first moment of the data, similarly $\frac{\Sigma fx^2}{n}=\nu_2$ is the second moment, $\frac{\Sigma fx^3}{n}=\nu_3$ is the third moment, and so on. The analogy to moments is here clearly apparent.

Each mathematical curve also may be conceived to have moments similar to those above for the data. Such moments are commonly designated by the symbol μ and must be capable of calculation from the equation of the curve.

Mathematical curve fitting.—The completion of almost every study of statistical data, as well as of observations and measurements, leads finally to adjusting a particular mathematical *curve represented by an equation* to fit a given group of data. This requires the evaluation of the constants of the equation so as to secure the best possible fit. The methods of least squares provide certain definite processes for accomplishing this result by the formation and solution of so-called normal equations. These methods define the curve of *best possible fit* to be one for which the sum of the squares of the residuals (the observed values minus the computed values) is a minimum. The solution of the problem in some of the more complex and

difficult cases by the methods of least squares is at times impracticable or even impossible, and Pearson[8] has developed and applied the method of moments to curve fitting. By this method the area under the mathematical curve is equated to the area represented by some smooth curve passing through the observations. In addition, one or more successive moments of the curve (expressed in terms of the constants of the equation) are equated to the corresponding moments of the data. A sufficient number of simultaneous equations is thus obtained to evaluate the constants of the mathematical equation.

The methods of moments and of least squares are identical when employed in fitting parabolic curves of any order to observations, but the solution by moments in the case of exponential and other transcendental equations, a number of which are indispensable in statistical studies, offer important advantages. At the best the processes are complex and tedious, but must be mastered to a certain extent by those students in these fields of inquiry who would attain the highest results.

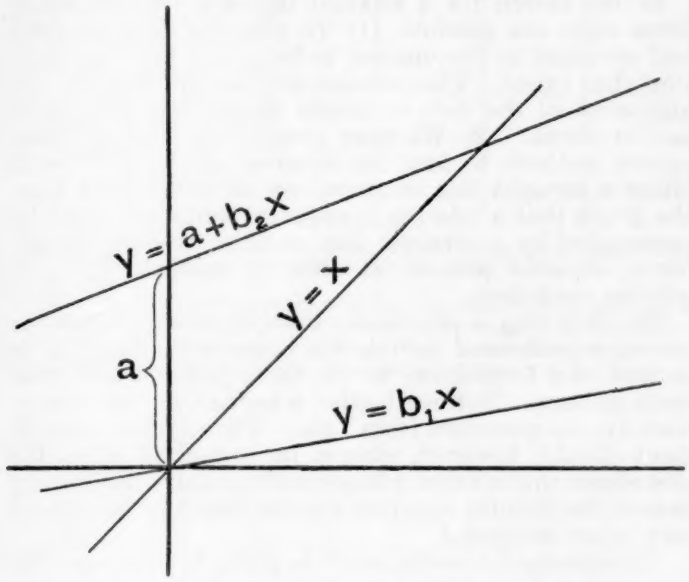

FIG. 9.—Illustrating straight lines and their equations.

A few of the multitude of mathematical equations that are likely to be employed to represent relations in statistical studies may be briefly noticed. Examples illustrating the least square methods of finding the most probable value of the constants in a few cases will be given later.

$$y_n = \frac{n}{\sigma\sqrt{2\pi}} e^{-\frac{x^2}{2\sigma^2}} \tag{7}$$

This apparently complex exponential equation for the normal frequency curve is very important and particularly interesting as it really contains but one undetermined constant. The most probable value of this may be very easily found for a given set of data.

$$\left.\begin{array}{ll} y = x & \text{(a)} \\ y = b_1 x & \text{(b)} \\ y = a + b_2 x & \text{(c)} \end{array}\right\} \tag{8}$$

These are equations of straight lines—(a) through the origin inclined 45°, (b) through the origin inclined at some other angle. Equations (a) and (b) are the kinds of equation obtained by calculations of the correlation coefficient, as will be shown later. Perfect correlation gives equation (a). Imperfect correlation leads to two equations of type (b), viz: $x = r\frac{\sigma_x}{\sigma_y} y$; $y = r\frac{\sigma_y}{\sigma_x} x$. Equation (c) is an inclined line cutting axis of y at distance a. (fig. 9.)

$$y = a + bx + cx^2 \tag{9}$$

The parabola has an equation representing a number of important physical laws and capable of being fitted to many groups of data, especially for limited ranges and where the law of relation does not involve points of inflection; that is, points at which the line changes its direction of curvature from concave to convex. Parabolic equations of the third and higher orders are frequently employed to represent more complex curves. In its general form the equation is

$$y = a + bx + cx^2 + dx^3 + \cdots \tag{10}$$

This form of equation is better known as the Maclaurin expansion. The addition of higher powers no doubt increases the elasticity of the curve, so to speak, and enables it to adjust its curvature to fit the observations, but a careful inquiry to ascertain the real physical nature of the relations it is desired to represent may lead to a form of equation with fewer terms that gives a better fit. So much depends on the proper choice of equation that remarks by Pearson[9] on this subject may be quoted here:

> The hasty assumption of some physicists and many engineers that a parabola of the form
>
> $$y = c_0 + c_1 x + c_2 x^2 + c_3 x^3 + \cdots$$
>
> is always a good thing, is to be deprecated as may be seen at once by considering what a poor fit is obtained in this way to material really expressed by such curves as
>
> $$y = y_0 e^{-cx^2},\ y = y_0 \sin nx,\ y(x+c) = b^2,\ \textit{etc.}$$
>
> To assume a curve of this form we must show the rapid convergency throughout the proposed range of the Maclaurin expansion, and this is not always feasible.
>
> We find physicist and statistician remarking that "the increased accuracy of the result obtainable by least squares would not be an adequate return for the labor involved," and then falling back on some more or less questionable process of determining the constants. This process may be graphical or arithmetical, but it is usually unsystematic in character and elastic in result.

After fitting one of his skew frequency equations of the form $y = y_0\left(1+\frac{x}{a}\right)^p e^{-\frac{px}{a}}$, also a series of parabolas up to the 6th order, to a group of data he remarks:

> The table compares these results with the successive parabolas up to the sixth and shows how a well selected curve with three constants can easily be superior to one with seven constants. This point is of special importance, for objections have been raised against the skew frequency curves just referred to on the ground that they give better fits than the normal curve because they have one or two more constants as the case may be. This is true; but they also give better fits than some other curves with double their number of constants!

$$\left.\begin{array}{l} xy = a^2 \\ xy = a + bx + cy \end{array}\right\} \tag{11}$$

The curves represented by these equations are of hyperbolic type with infinite branches at right angles to each other. In the first, the branches are asymptotic to the axes (that is, approach and meet the axes at in-

[8] *Pearson, K.* On the systematic fitting of curves to observations and measurements. Biometrika, April, 1902, 1:265.

[9] Biometrika 1: 266, 267, 293.

finity), in the second the asymptotes are at distances $\frac{a}{b}$ and $\frac{a}{c}$ from the axes.

$$y=ae^{bx} \tag{12}$$

This represents one of many forms of exponential equations. Its logarithmic form is,

$$\log y=a_1+b_1x \tag{13}$$

in which $a_1=\log a$ and $b_1=b \log e$.

Much careful attention must be given to finding the best values of the constants of such equations so as to properly fit the data. The textbooks should, but do not emphasize the fact that the least square methods ordinarily employed to determine the most probable values of a_1 and b_1 in equations like (13) may in the case of inexact data lead to an equation that fits the observations wretchedly.

The matter is too involved to discuss in the present paper.

$$y=a+b \sin nx+c \cos nx+, \text{ etc.} \tag{14}$$

Data which exhibits periodicity may be represented best by trigonometrical equations like (14). Additional terms with successive multiples of the angle may be added for more complex forms. While theoretically such an equation with sufficient terms can be made to represent any periodic curve whatsoever or fragment thereof, the work of harmonic analysis and curve fitting of complex curves like the tides, etc., can be successfully carried out only with elaborate instruments which have been invented for the purpose.

CORRELATION.

Having plotted his data the student may select from the several types of equations indicated in the foregoing the one he judges will best represent his problem and compute the constants thereof, thus securing the most definite and exact measure of relation possible between the quantities under consideration.

The procedure just described of plotting and curve fitting has to do with correlation in the highest sense of that word. Nevertheless, that definite procedure can not always be carried out satisfactorily, and the word correlation has come to be applied to a particular process of discovering interrelation of a limited character between statistical data in cases in which it may be uncertain even that any relation exists. Eagerness to utilize any mathematical process to aid in resolving the perplexities of the interrelations of groups of statistical data of all kinds may have led some, before examining the actual mathematical significance and basis of the coefficient of correlation, to form an exaggerated estimate of its value and possibilities. The following quotation from Yule[10] indicates clearly the exact nature of the problem and the purpose served by the correlation coefficient.

> The complete problem of the statistician like that of the physicist is to find formulæ or equations which will suffice to describe approximately these curves.
>
> In the general case this may be a difficult problem, but in the first place it often suffices, as already pointed out, to know merely whether on an average high values of the one variable show any tendency to be associated with high or with low values of the other, a purpose which will be served very fairly by fitting a straight line; and, further, in a large number of cases, it is found either (1) that the means of arrays lie very approximately round straight lines, or (2) that they lie so irregularly (possibly owing only to paucity of observations) that the real nature of the curve is not clearly indicated, and a straight line will do almost as well as any more elaborate curve. In such cases—and they are relatively more frequent than might be supposed—the fitting of straight lines to the means of arrays determines all the most important characters of the distribution. We might fit such lines by a simple graphical method, plotting the points representing means of arrays on a diagram like those of figures 36–38, and "fitting" lines to them, say, by means of a stretched black thread shifted about till it appeared to run as near as might be to all the points. But such a method is hardly satisfactory, more especially if the points are somewhat scattered; it leaves too much room for guesswork and different observers obtain very different results. Some method is clearly required which will enable the observer to determine equations to the two lines for a given distribution, however irregularly the means may lie, as simply and definitely as he can calculate the means and standard deviations.

The *function of the correlation coefficient* is therefore clearly defined, namely, that of an index of the extent to which the relation between certain data may be represented by a straight line. A low correlation coefficient must not be interpreted to mean no relation necessarily, but that if a relative exists it is not well represented by a straight line.

In the search for a relation between two variables, three steps are possible: (1) To plot the data, selected and arranged in the manner to bring out best any relation that exists. This relation will be indicated by the alignment of the dots or points along some recognized line or curve. (2) We may proceed at once by least-square methods to find the equation of the plot, be it either a straight line or curve; or (3) concluding from the graph that a relation is apparent and that it can be represented by a straight line quite as well as by any curve, we may proceed at once to compute the correlation coefficient.

The first step is practically indispensable. When the second is performed the relation between the variables is defined and formulated in the most positive and complete manner. Nothing further is needed, for the reasons stated in the quotation from Yule. The correlation coefficient should, however, always be computed when the plot shows that a linear relation suffices and when for any reason the definite equation contemplated in the second step is not computed.

The correlation coefficient [11] is given by the equation

$$r=\frac{\mathrm{P}}{\sigma_x\sigma_y}=\frac{\Sigma(xy)}{n\sigma_x\sigma_y}.$$

$\frac{\Sigma(xy)}{n}$ is the sum of the products of the departures of x from its mean multiplied by the departure of the corresponding y from its mean—all divided by the number of pairs n. The expression σ_x is the standard deviation of the x departures; σ_y is the standard deviation of the y departures.

The following note by J. Warren Smith is of interest:

> *Value of the correlation coefficient.*—In the past 10 years the writer has used the correlation coefficient as a practical method for showing the measure of the effect of the rainfall and temperature for definite periods and areas upon the yield of various crops.
>
> The practice has been to first test the possible relation between the factors by means of the dot chart or curve chart or by some of the other recognized methods of sampling. During this time nearly 1,000 calculations have been made for the correlation coefficient, and no case is recalled when a low coefficient was found to be due to the law of relation being nonlinear. In every instance when using the dot chart, where there was a scattering of the dots, there was a low coefficient, and whenever there was a high value the dots were grouped around a fairly diagonal straight line. The dot chart may be made from the departure values or, what is still better, from the actual figures without the extra work of obtaining the departures from the normals.

[10] *Yule, G. U.* Introduction to theory of statistics. p. 169.

[11] *Yule, U. G.* Introduction to the theory of statistics. 1910. p. 171, Equations (1) and (4).

Figure 10 is an example of the simplest method of determining by the dot chart whether the relation between two factors is linear. This chart shows the relation between the average rainfall for the States of Indiana, Illinois, Iowa, and Missouri during the month of July and the average yield of corn per acre. In this case it will be seen that there is a fairly regular increase in the corn yield with an increase in the rainfall, and while there may be a slight tendency to a decrease in yield, with the greatest rainfalls, nevertheless this is not significant. My value for the correlation coefficient was $+0.61 \pm 0.08$.

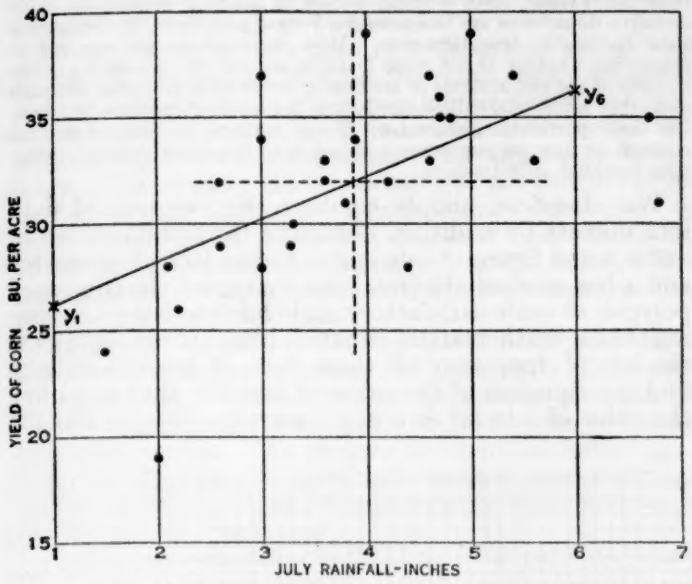

FIG. 10. Dot chart of data on the rainfall and the yield of corn in the States of Iowa, Missouri, Illinois, and Indiana. Also straight line of closest fit.

Figure 11 indicates the position of the dots when the line of closest fit is nearly parallel with one of the axes—in this case, with the axis of abscissæ. The correlation coefficient from this calculation is only -0.14, thus agreeing with the promiscuous scattering of the dots.

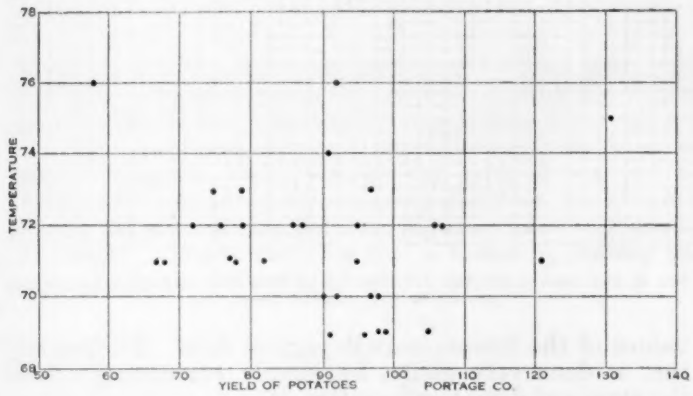

FIG. 11. Dot chart of yield of potatoes and temperature indicating little or no relation because straight line of approximate fit is nearly or quite parallel to one axis.

Figure 12, on the other hand, shows at once that one may expect a high correlation coefficient value, but instead of a straight diagonal line from the intersection of the axes being the closest fit, the line runs from the extremes of the axes. This shows that the correlation coefficient will have a minus sign, because as one factor increases the other decreases, instead of both increasing together as in figure 10. This figure shows the relation between the mean temperature for the month of July and the average yield of potatoes for the State of Ohio. * * *

The writer began the use of this method of studying the relation between weather and crop yields as an experiment, not knowing that it had ever before been used for this purpose. We have since then, however, learned that Mr. G. Udny Yule and Mr. R. Hooker had already recognized its value in this connection and had used it extensively. We wish to strongly urge the continuation of the use of the correlation table in studying weather and crops, with proper preliminary examination, until some better method has been evolved.—*J. Warren Smith.*

Emphasis has been laid on the necessity of limiting the application of the methods of correlation only to data in

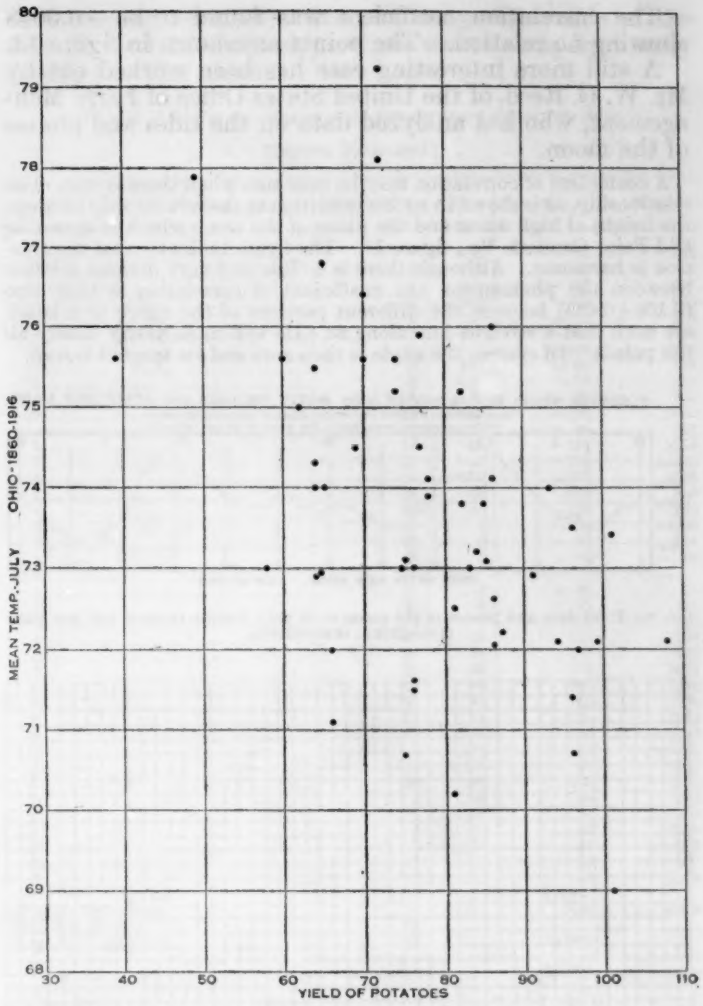

FIG. 12. Dot chart of yield of potatoes and temperature in which line of approximate relation inclines to the left.

linear relation. The following values of x and y representing points upon a parabola were submitted without explanation, to have the coefficient of correlation computed.

x.....	19.6	15.9	19.2	15.0	13.9	18.8	8.8	17.7	10.2	20.0	12.8
y.....	33	39	26	20	41	35	45	24	16	30	18

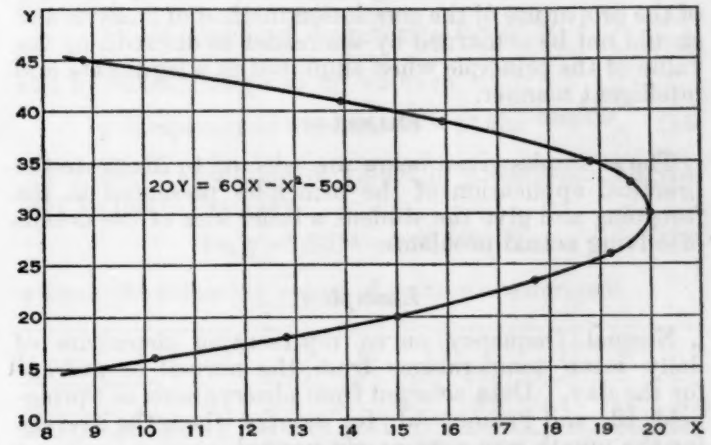

FIG. 13. Dots on parabolic curve. Coefficient of correlation is very nearly zero, because data can not be represented by a straight line.

The correlation coefficient was found to be -0.0048 showing no relation. The points are shown in figure 13.

A still more interesting case has been worked out by Mr. W. G. Reed, of the United States Office of Farm Management, who has analyzed data on the tides and phases of the moon.

A coefficient of correlation may be near zero when there is very close relationship, as is shown in such a condition as the relationship between the height of high water and the phase of the moon which is shown for Old Point Comfort, Va., figure 14. The figure indicates that the relation is harmonic. Although there is a close and very definite relation between the phenomena, the coefficient of correlation is near zero (0.106 ± 0.088) because the different portions of the curve of relation are such that a straight line along an axis will most nearly satisfy all the points. Of course, the angle is then zero and its tangent is zero.

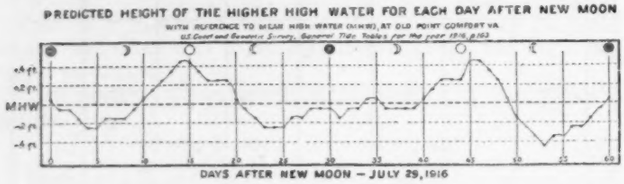

FIG. 14. Tidal data and phases of the moon with very definite relation but low value of coefficient of correlation.

We, therefore, simply combine the two sets of data into one set by addition, obtaining the results shown in Table 2 and figure 17. In spite of some lack of symmetry and a few marked abnormalities we regard the frequency polygon as quite satisfactory and characteristic. Assuming that a mathematical equation like (1) best represents the law of frequency of these data, it remains only to find the equation of the curve of best fit; that is, to find the value of h in (2) or σ in (5) corresponding to the 731 values of the temperature departure data. Fortunately this is done very easily, by simply calculating σ from the standard deviation equation (4).

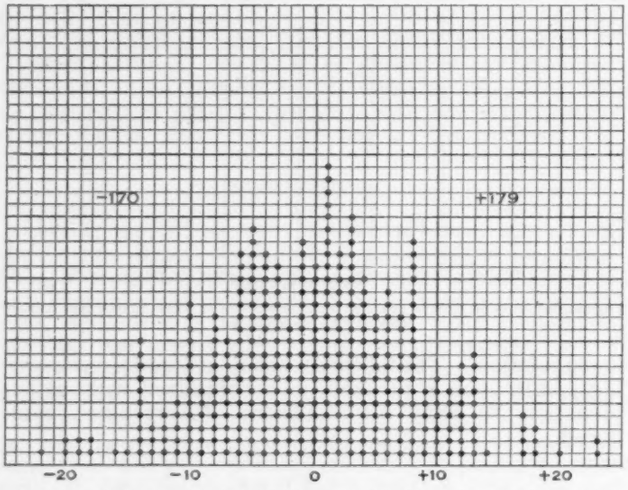

FIG. 15. Dot chart of frequency of departure of July daily mean temperature from normal for many years for Springfield, Ill.

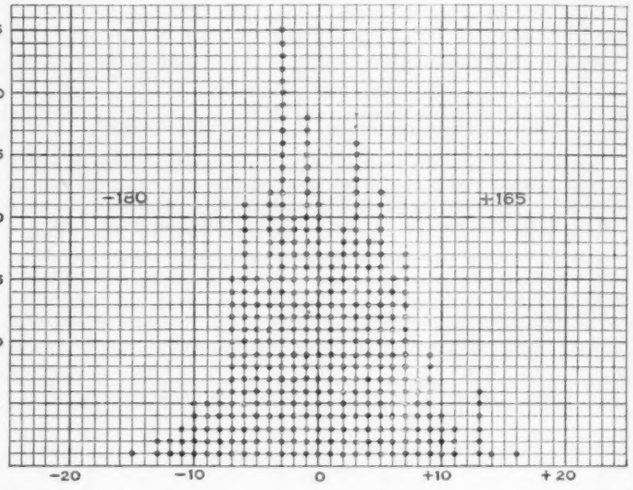

FIG. 16. Dot chart of frequency of departure of July daily mean temperature from normal for many years for Fresno, Cal.

These illustrations are given to show the importance of the proper use of the correlation method of analysis and should not be construed by the reader as discrediting the value of the principle when employed in a legitimate and intelligent manner.

EXAMPLES.

The examples given below are selected to illustrate the practical application of the principles presented in the foregoing and give the student a fuller idea of the details of solving actual problems.

Example 1.

Normal frequency curve representing departure of daily mean temperatures from the normal or average for the day. Data selected from observations at Springfield, Ill., and Fresno, Cal., for months where the average for the month was very nearly normal.

Figures 15 and 16 illustrate by dots the departures from the normal for each day for a year's observations at each station. The accuracy of the data is not now a question, as its present purpose is to serve simply as an example.

The relatively small amount of data as well as the inexact manner of its compilation and the tendency of climatic data to exhibit wide fluctuations cause marked irregularities and abnormalities to appear in these frequency polygons, even when several hundred observations are available. The data for Springfield show more dispersion than those for Fresno, with a slight excess of positive departures. The negative departures are in excess for Fresno and there the departures show noticeably less dispersion. More observations are required to determine whether or not these features are real characteristics of the climate of the two stations or are due to errors from dropping decimals and other accidental causes incident to the method employed in forming these particular departures. These matters, however, need not concern us now, as our present object is to illustrate methods rather than establish definite facts.

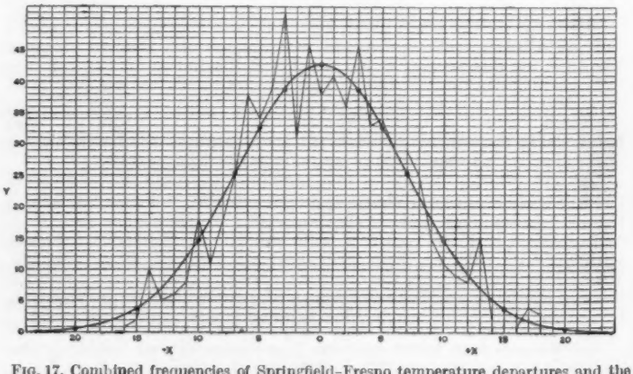

FIG. 17. Combined frequencies of Springfield-Fresno temperature departures and the normal frequency curve of best fit. (See equation 16.)

Practical calculation of the standard deviation.—Table 2 gives the data and steps in the computation in full. The calculation is such an important one on account of its frequent occurrence in physical and statistical work that it justifies special notice.

In equation (4) on page 557, Sigma x^2 (Σx^2) must represent the *least sum of squares*. As already explained this sum will be the least only when the departures are taken with respect to the true mean.

Now, ordinarily, this kind of a departure can not be tabulated, *accurately*, because the mean value generally ends in a long decimal which it is impracticable to retain in the computations. Nevertheless whatever part of the mean is rejected causes the sum of the squares to be too large. Fortunately the exact value of the excess can be easily found so that in practice it is more convenient to select some arbitrary number, generally near the mean, and form the departures with respect to this value. The minimum sum of squares can then be easily found, as also the exact value of the mean.

Obviously, we need some convenient nomenclature to indicate to the eye whether, for example, a given sum of squares, as also other related quantities, is based on departures from the true mean or from some arbitrary reference number. We propose to adopt the following:

Σx, Σx^2, Σxy, etc., designate the sums of the quantities represented by x, x^2, xy, etc., when departures are calculated from the true mean.

$[x]$, $[x^2]$, $[xy]$, will indicate the sums of departures taken from some arbitrary number.

We now need to know the relation between Σx^2 and $[x^2]$. According to Yule [12] and other authorities this relation is indicated in the customary equation for the standard deviation, which may be written thus in our notation:

$$\sigma = \sqrt{\frac{[x^2] - nd^2}{n}}$$

in which d is the difference between the true mean and the base or reference number used in forming the departures. While mathematically exact this form of the equation for σ is faulty and troublesome from the computer's point of view, because the term d^2 can not be accurately computed by squaring d unless the latter is computed with more significant figures than is otherwise necessary. The remedy for this is found by stating the equation in the following identical form:

$$\sigma = \sqrt{\frac{[x^2] - \frac{[x]^2}{n}}{n}}$$

where $[x]^2$ is the algebraic sum of the departures *squared*. Ordinarily this sum will be computed any way as a check on the work. It will generally be a small number whose square can be exactly computed, as also the quotient $[x]^2/n$, thus giving with the least amount of work the minimum sum of squares $\Sigma x^2 = [x^2] - [x]^2/n$. All the work is shown in Table 2. If M is the approximate mean or base number, the true mean A is found from the following equation:

$$A = M - [x]/n$$

In the present example the quantity A has no special significance in connection with the temperature data because of the manner in which the departures were taken. It does, however, indicate that the normal curve of best fit is shifted by 0.0506° toward the positive side of the axis Y, and that the departures were taken from very nearly the true mean.

[12] *Yule, G. U.* Introduction to the theory of statistics. p. 135, equation (4) transposed.

TABLE 2.—*Fresno-Springfield temperature departure data.*

[Degrees Fahrenheit.]

Departures, x.	Number, y.	x^2.	xy.	x^2y.
−22	1	484	− 22	484
−20	2	400	− 40	800
−19	2	361	− 38	721
−18	2	324	− 36	648
−16	1	256	− 16	256
−15	2	225	− 30	450
−14	10	196	−140	1960
−13	5	169	− 65	845
−12	6	144	− 72	864
−11	8	121	− 88	968
−10	18	100	−180	1800
− 9	11	81	− 99	891
− 8	18	64	−144	1152
− 7	25	49	−175	1225
− 6	38	36	−228	1368
− 5	34	25	−170	850
− 4	39	16	−156	624
− 3	51	9	−153	459
− 2	31	4	− 62	124
− 1	46	1	− 46	46
± 0	37	.....	.....	.....
+ 1	41	1	+ 41	41
2	36	4	72	144
3	46	9	138	414
4	33	16	132	528
5	34	25	170	850
6	29	36	174	1044
7	29	49	203	1421
8	25	64	200	1600
9	15	81	135	1215
10	11	100	110	1100
11	9	121	99	1081
12	8	144	91	1152
13	15	169	195	2535
14	2	196	28	392
16	1	256	16	256
17	4	289	68	1156
18	3	324	54	972
20	1	400	20	400
23	2	529	46	1058
Positive departures	344	.....	1997	33894
Zero departures	37	.....	.....	.....
Negative departures	350	.....	−1960	.....
Total	$n=[y]=731$	.....	$[xy]=+37$	$[x^2y]=33894$

$$\frac{[xy]}{n} = +0.0506.$$

$$\text{Minimum sum of squares} = 33894 - \frac{(37)^2}{n} = 33892.13.$$

$$\text{Standard deviation} = \sigma = \sqrt{\frac{33892.13}{731}} = 6.809.$$

The final result of the analysis of the Springfield–Fresno temperature data, assuming that the same law applies to both stations, is the frequency law given by the following

$$\sigma \text{ (standard deviation)} = 6.809° \text{ F.}$$

and by substituting σ in (5) we have

$$y \text{ (frequency of departures)} = 42.83e^{-0.010783x^2}. \quad (15)$$

For easy calculation of values of y the equation (15) may be put in the form

$$\log y = 1.6374 - 0.004683x^2 \quad (16)$$

whence the following values of x and y are derived:

x	0	3	5	7	10	15	20	25
y	42.8	38.9	32.7	25.2	14.7	3.8	0.6	0.05

We wish to know how much confidence may be placed in these final results. This is ascertained by computing

the probable error[13] of the standard deviation, which turns out $\sigma = 6.809° \pm 0.12°$. This indicates that when the departures do not differ greatly from the standard deviation the results obtained from (15) or (16) are not likely to be more than $\pm 2\%$ in error.

The student must catch the significance of the values of y computed by means of (16). According to these data the temperatures will be the same as the normal for the day on 42.8 days out of 731, i. e., a period of two years (one a leap year). It will go 3 degrees above or below the normal 39 times. The departure will be $\pm$ 15 degrees on less than 4 days in these two years. Half of all the departures will be above and half will be below the value of the probable departure[14] which will be $0.6745\,\sigma = 4.59°$. The table shows 360 out of 731 values between $+4$ and -4 degrees, a slight excess over the number called for by the curve, but still a close agreement. Suppose we wish to know the percentage of departures that will exceed, say 10, 15, etc. degrees? Questions of this kind are readily answered by reference to a table of the probability integral. Davenport's Table IV gives, for the entry $10/\sigma = 1.47°$, the value 0.42922, which represents the half area of the probability curve out to $x = +10$ degrees. The area of half the curve is 0.50000, therefore the portion beyond $x = +10$ will be 0.071. An equal extension will lie beyond $x = -10$, hence the percentage of departures beyond ± 10 degrees will be $2 \times 0.071 = 14\%$. The percentage beyond 15 degrees will be 2.8%. These results indicate that about 11% of the departures will have values between 10 and 15 degrees.

The foregoing can not be stated as positive facts concerning Fresno and Springfield climates, because the data were not sufficiently representative to justify positive statements, but the examples serve to illustrate how such results can be obtained by accurate mathematical methods. Moreover, we have the satisfaction of knowing that frequency curves, when properly deduced in the manner indicated even from seemingly irregular and insufficient data, nevertheless express a definite law of occurrence of deviations that not only fits the data employed the best possible, but is the general law to which the data will conform more and more closely as the length of the records is prolonged and the number of observations multiplied.

Problem II.

To find the constants of the equation of the straight line of best fit to the data in Prof. Smith's example, figure 10, giving the relation between July rainfall for the States of Indiana, Illinois, Iowa, and Missouri. Let $y =$ yield of corn per acre for this territory and r the July rainfall. These data give a series of observation equations for a straight line of the type

$$y = a + b\,r,$$

and our problem is to determine the best or most probable values of a and b. The data and computations are given in Table 3, and figure 10 shows the data in graphic form. A few of the observation equations may be written thus:

$$\begin{aligned} 34 &= a + 3.9b \\ 33 &= a + 4.6b \\ 26 &= a + 2.2b \\ &* \quad * \quad * \quad * \quad * \\ 31 &= a + 6.8b \end{aligned}$$

There will be in all 28 equations and, according to the methods of least squares, the most probable values of a and b are given by the solution of two normal equations.[15]

Rule.—The normal equation for a is formed by multiplying each observation equation by the coefficient of a (with its proper sign) in that equation. *The sum of the resulting equations is the normal equation for a.*

Likewise the normal equation for b is formed by multiplying each observation equation by the coefficient of b in that equation. *The sum of the resulting equations is the normal equation for b.*

The two normal equations thus obtained are simultaneous equations and their solution gives the most probable values of a and b.

Carrying out the operations indicated the normal equations may be written in this form—

$$\begin{aligned} \Sigma y &= na + b\Sigma r \\ \Sigma ry &= a\Sigma r + b\Sigma r^2 \end{aligned}$$

These equations give

$$b = \frac{n(\Sigma ry) - (\Sigma r)(\Sigma y)}{n(\Sigma r^2) - (\Sigma r)^2} = 2.027$$

When b is found,

$$a = \frac{\Sigma y - b(\Sigma r)}{n} = 24.07$$

In these equations Σr is the sum of the rainfall and Σy the sum of the yields. Σry is the sum of the products, rainfall by yield, and Σr^2 is the sum of the squares of the rainfall. These values are similar to quantities that require to be computed in forming the correlation coefficient and the non-mathematical student does not need to know how to deduce all the equations, but simply to be able to perform the computations shown in Table 3.

TABLE 3.—*July rainfall and yield of corn for the States of Iowa, Missouri, Illinois, and Indiana.*

Year.	Rain, r.	Yield, y.	r^2	ry	Computation.
	Inches.	*Bu. p. ac.*			
1888	3.9	34	15.21	132.6	
1889	4.6	33	21.16	151.8	
1890	2.2	26	4.84	57.2	
1891	3.0	34	9.00	102.0	
1892	4.4	28	19.36	123.2	
1893	3.0	28	9.00	84.0	
1894	1.5	24	2.25	36.0	$\Sigma r = 109.0$
1895	4.7	35	22.09	164.5	$(\Sigma r)^2 = 11,881$
1896	6.7	35	44.89	234.5	$\Sigma y = 895$
1897	3.3	29	10.89	95.7	$\Sigma r^2 = 472.56$
1898	3.6	32	12.96	115.2	$\Sigma ry = 3,581.9$
1899	3.6	33	12.96	118.8	$(\Sigma r)(\Sigma y) = 97,555$
1900	4.8	35	23.04	168.0	$n(\Sigma r^2) = 13,231.68$
1901	2.0	19	4.00	38.0	$n(\Sigma ry) = 100,293.2$
1902	5.4	37	29.16	199.8	
1903	3.8	31	14.44	117.8	$b = \frac{100,293.2 - 97,555}{13,231.68 - 11,881}$
1904	4.2	32	17.64	134.4	
1905	5.0	38	25.00	190.0	$= \frac{2,738.2}{1,350.68} = 2.027$
1906	3.0	37	9.00	111.0	
1907	5.6	33	31.36	184.8	
1908	3.3	30	10.89	99.0	$a = \frac{895 - 220.943}{28} = \frac{674.057}{28}$
1909	4.7	36	22.09	169.2	
1910	4.6	37	21.16	170.2	$= 24.07$
1911	2.6	32	6.76	83.2	
1912	4.0	39	16.00	156.0	
1913	2.6	29	6.76	75.4	
1914	2.1	28	4.41	58.8	
1915	6.8	31	46.24	210.8	
Sums	109.0	895	472.56	3,581.9	

[13] *Davenport, C. B.* Statistical methods, 1914, p. 16. $E_\sigma = \pm 0.6745\sigma/\sqrt{2n}$.

[14] See above under "Probable error," p. 557.

[15] *Merriman.* Methods of least squares. New York, 1915. par. 48. *Comstock.* Method of least squares. Boston, 1889. pp. 19 and 23.

The equation of the straight line that best fits the data of Table 3 and represents the relation between the yield of corn and the July rainfall is

$$y = 24.07 + 2.03r.$$

This equation indicates that if r is 1, $y = 24.07 + 2.03 = 26$. If $r = 6$, $y = 24.07 + 12.16 = 36$. Two points like these suffice to locate the line of best fit on the diagram, figure 10, as at y_1 and y_6.

The coefficient +2.03 means that each inch of increase in July rainfall will add 2.03 bushels per acre to the yield of corn in the States considered. It must be understood, of course, that the law of relation represented by the equation is purely an arbitrary one and applies only to conditions *within the range of the records discussed.* Moreover the relation is only approximate, as is shown by the comparatively widely scattered distribution of the dots in figure 10. Obviously other factors than rainfall influence the yield and should be considered, but the line found by the foregoing method is, in a sense, a first approximation in the discovery of the relations between the statistical data considered and is identical, although expressed in different units of measurements, with the line defined by the correlation coefficient, $r = 0.61$, previously found.

Problem III.

Variation in December minimum temperatures at Washington, D. C., 1872 to 1915, inclusive. These data afford an instructive illustration of the application of the methods of statistics to climatology. From 1872 to 1888 the observations were made at the old office near 17th and G streets NW., and after 1889 at the present office at 24th and M streets NW. The data were first analyzed in two groups corresponding to the locations of the office; and finally treated as a whole independent of location, since there is no evidence of any systematic difference accompanying the removal of the office.

Table 4 gives the number of times (y_n) that the various minimum temperatures were observed in the whole period of 44 years, as also for the separate intervals of 17 years in the old location and 27 years in the present position.

In figure 18 the three groups of data are shown reduced to a 10-year basis of record, including the normal frequency curve of best fit for the whole series. The separate curves for the two groups of data, old and new office, differ too little from the one for the whole period to justify drawing them in, but the corresponding ordinates for all the curves are given in Table 4.

TABLE 4.—*Computed values of* y_n *for temperature data, 10-year basis.*

	Old office.	New office.	Combined.
x	y_n	y_n	y_n
±0	13.31	14.52	13.93
±2	13.00	14.12	13.58
±4	12.13	13.00	12.58
±5	11.52	12.22	11.88
±7	10.02	10.36	10.21
±10	7.46	7.29	7.39
±15	3.62	3.08	3.34
±20	1.31	0.92	1.10
±25	0.36	0.20	0.26
±30	0.07	0.03	0.05
±35	0.1	0.003	0.01

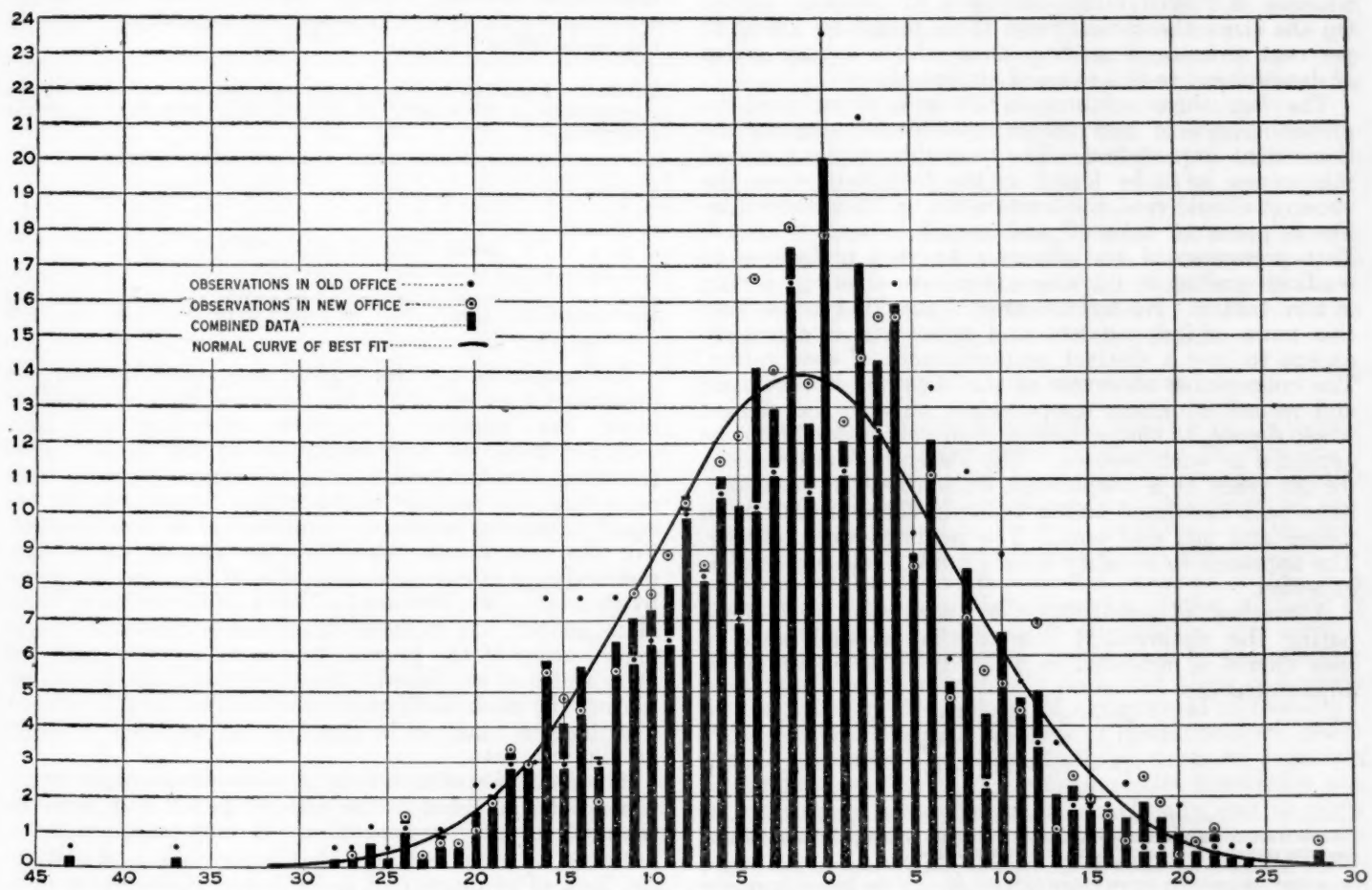

FIG. 18. The departures, above and below 30° F., of minimum temperatures of Washington, D. C., for December, 1872 to 1915. Also normal frequency curve of best fit.

The results of the calculation of the frequency curves, presented in Table 5, show the close agreement in the data.

TABLE 5.

Series.	Average minimum temperature, December.	Standard deviation, σ.	Probable variation, $\frac{2}{3}\sigma$.	Preponderance of even temperatures.		
				Even temperature.	Odd temperature.	Per cent.
	°	°				
Old office, 17 years	28.6	9.29	6.2	325	201	1.62
New office, 27 years	28.6	8.52	5.7	466	371	1.26
Whole series, 44 years	28.6	8.81	5.9	792	571	1.39

Preponderance of even temperatures.—A striking abnormality consisting of the preponderance of *even* temperature values is obvious from an inspection of figure 18. This is likely to be characteristic of a large proportion of meteorological data from which decimal fractions or unnecessary digits have been disposed of according to the customary rule.[16] The minimum temperatures in the present case were read and recorded to the nearest tenth of a degree, and the fractions were subsequently disposed of according to the well-known rule which changes all readings ending in 5 to a number ending in an *even* digit. The effect of this rule upon the frequency distribution is to cause all observed temperatures between, say 9.5° and 10.5°, to be classified under 10° and, similarly, for any other *even* value, whereas any odd temperature like 7° comprises only the values betweem 6.6° and 7.4°. The latter, that is the odd class, comprises nine values, whereas the even class comprises 11 possible values. On the strict theoretical basis there should be about 22 per cent more even readings than odd in a large group of data subject to this cause of abnormality.

The last three columns in Table 5 show that the preponderance of *even* values considerably exceeds the theoretical expectation. The probable explanation of this excess is to be found in the fact that when the observer should read the fraction 0.4 or 0.6 he nevertheless is prone to take off and record a fraction of 0.5. This proneness of the observer to give preference to readings ending in 0.5 also extends to readings ending in zero tenths. No serious error of any kind arises from this more or less inherent and systematic abnormality except to give a distinct preponderance of *even* values. The cooperative observers of the Weather Bureau read and record minimum temperatures only to the nearest whole degree, so that excess of even values should not be expected in such records. The December observations for 20 years at a cooperative station near Washington, have been tabulated and it is found there are 307 even values and 303 odd ones. Ten readings were missing. The approach to equality is here quite as close as can be expected.

A method of equalizing the distribution and eliminating the abnormality due to the preponderance of *even* values is indicated in Table 6. The equations of adjustment are:

$$B = a + 2b + c,$$
$$C = b + 2c + d,$$
$$D = c + 2d + e,$$
etc.

[16] The Weather Bureau rule for disposing of decimals is given in its "Instructions for preparing meteorological forms," § 123, and reads as follows:
"123. In dropping decimals, if the figure to be dropped is greater than 5 (or 5 with a remainder) the preceding figure will be increased by 1. If the decimal figure to be dropped is 5 exactly, the preceding figure when odd will be increased by 1, and when even it will remain unchanged. If the figure to be dropped is less than 5, retain the preceding figure unchanged."

TABLE 6.—*Illustrating elimination of abnormality due to preponderance of even values of data.*

Class.	Range in class.	Frequency.	
		Observed.	Equalized.
4	11	a = 0	A = 0
5	9	b = 0	B = 8
6	11	c = 8	C = 18
7	9	d = 2	D = 27
8	11	e = 15	E = 37
9	9	f = 5	F = 32
10	11	g = 7	G = 19
11	9	h = 0	H = 7
12	11	i = 0	I = 0

The equalized frequencies each comprise 40 elements, or we may regard them each as four times the true adjusted values. Fractions will be introduced, however, if we divide by 4, and for easy and accurate computation it will generally be best to use the adjusted values directly and divide by 4 at the end of the computation, if desired.

The whole series of December minimum temperatures for Washington were equalized for odd and even values by the rule mentioned above with the result:

	Even.	*Odd.*	*Total.*
Data as tabulated	792	571	1363
Data as adjusted	2726	2726	5452

Probability of a given departure.—Among the useful deductions to be drawn from the mathematical analysis of the mimimum temperature data of Problem III are the probabilities of occurrence of given departures, or departures between certain limits. Some such results are given in Table 7, which is constructed from tables of the probability integral.

TABLE 7.—*Number of days in 100 years on which the December mimimum temperature at Washington, D. C., will differ from 28.6° by certain amounts.*

[Based on 44 years' record. Standard deviation $\sigma = 8.88°$.]

Departure.	$\leq \pm 5°$ or less.	$\geq \pm 5°$.	$\geq \pm 10°$.	$\geq \pm 15°$.	$\geq \pm 20°$.	$\geq \pm 25°$.	$\geq \pm 30°$.	$\geq \pm 35°$.	$\geq \pm 40°$.
x/σ	0.563	0.563	1.126	1.689	2.252	2.815	3.378	3.941	4.505
Number of days	1,322	1,778	807	283	75.4	15.1	2.26	0.25	0.02

An examination of the original data shows that no plus departure in excess of 30° has occurred, but, on the other hand, two negative departures exceeding 30° have occurred in the 44 years comprised by the record. Furthermore, a critical examination of figure 18 clearly indicates that the positive and negative departures are not equal in number or strictly symmetrical in arrangement. For the best results, therefore, we require an unsymmetrical type of curve, such as some of the types proposed by Pearson. Mr. Howard R. Tolley, of the Office of Farm Management, has recently developed a relatively simple modification of the normal frequency equation not yet described and published,[17] that is appropriate for representing the moderately unsymmetrical or skew frequency distributions likely to be found in the analysis of nearly all climatic data.

The discussion of unsymmetrical distributions, however, can not be included in the present paper and must be reserved for later presentation. It may be appropriate, however, to point out here that systematic and consistent lack of symmetry of a frequency distribution indi-

[17] To appear in this REVIEW for November, 1916.

cates that some one or more influences are acting which tend to make deviations of a particular kind or class to preponderate. The thing to do, therefore, is to discover and eliminate the preponderating influence. This procedure should ultimately suffice to reduce all distributions simply to the normal error curve of best fit.

Example IV.

Practical calculation of coefficient of correlation, using data in Example II on the relation between July rainfall for the States of Indiana, Illinois, Iowa, and Missouri, and the yield of corn per acre.

Table 8 gives the data and the computations in full. In the case of the rainfall the departures are computed from the arbitrary number 4.0, and 32 is an arbitrary base number used in tabulating the variations in yield of corn.

As already explained on page 563 in the practical calculation of the standard deviation, the use of the arbitrary base numbers causes the sums of the squares to be too large. The sum of the products represented by xy is also too large for the same reason. It was shown that the minimum sum of squares is given by the equation

$$\Sigma x^2 = [x^2] - \frac{[x]^2}{n}.$$

TABLE 8.—*Coefficient of correlation between July rainfall in Indiana, Illinois, Iowa, and Missouri and the yield of corn per acre.*

[By J. Warren Smith.]

	Rainfall.			Yield of corn.			
Year.	r	Departure, x	x^2	Y	Departure, y	y^2	xy
	Inches.			*Bushels.*			
1888	3.9	− 0.1	0.01	34	+ 2	4	− 0.2
1889	4.6	+ 0.6	0.36	33	+ 1	1	+ 0.6
1890	2.2	− 1.8	3.24	26	− 6	36	+ 10.8
1891	3.0	− 1.0	1.00	34	+ 2	4	− 2.0
1892	4.4	+ 0.4	0.16	28	− 4	16	− 1.6
1893	3.0	− 1.0	1.00	28	− 4	16	+ 4.0
1894	1.5	− 2.5	6.25	24	− 8	64	+ 20.0
1895	4.7	+ 0.7	0.49	35	+ 3	9	+ 2.1
1896	6.7	+ 2.7	7.29	35	+ 3	9	+ 8.1
1897	3.3	− 0.7	0.49	29	− 3	9	+ 2.1
1898	3.6	− 0.4	0.16	32	± 0	0	.....
1899	3.6	− 0.4	0.16	33	+ 1	1	− 0.4
1900	4.8	+ 0.8	0.64	35	+ 3	9	+ 2.4
1901	2.0	− 2.0	4.00	19	−13	169	+ 26.0
1902	5.4	+ 1.4	1.96	37	+ 5	25	+ 7.0
1903	3.8	− 0.2	0.04	31	− 1	1	+ 0.2
1904	4.2	+ 0.2	0.04	32	± 0	0	.....
1905	5.0	+ 1.0	1.00	38	+ 6	36	+ 6.0
1906	3.0	− 1.0	1.00	37	+ 5	25	− 5.0
1907	5.6	+ 1.6	2.56	33	+ 1	1	+ 1.6
1908	3.3	− 0.7	0.49	30	− 2	4	+ 1.4
1909	4.7	+ 0.7	0.49	36	+ 4	16	+ 2.8
1910	4.6	+ 0.6	0.36	37	+ 5	25	+ 3.0
1911	2.6	− 1.4	1.96	32	± 0	0	.....
1912	4.0	± 0.0	0	39	+ 7	49	.....
1913	2.6	− 1.4	1.96	29	− 3	9	+ 4.2
1914	2.1	− 1.9	3.61	28	− 4	16	+ 7.6
1915	6.8	+ 2.8	7.84	31	− 1	1	− 2.8
		−16.5	.....		−49	.....	+109.9
		+13.5	48.56		+48	555	− 12.0
$[x]$ =	.....	− 3.0	.....	.....	− 1	.....	+ 97.9
Base No. = 4.0				32			
Mean = $4.0+\frac{[x]}{28}$ = 3.89				= $32+\frac{[y]}{28}$ = 31.96			

In a similar manner, using the symbols explained on page 563, the exact value of the sum of the products, xy, may be found from the computed sum by the following equation:

$$\Sigma xy = [xy] - \frac{[x][y]}{n}.$$

Accordingly, we have the following formulæ for computation of the coefficient of correlation:

Standard deviation (rainfall),

$$\sigma_x = \sqrt{\frac{[x^2] - \frac{[x]^2}{n}}{n}} = \sqrt{\frac{48.239}{28}} = 1.313 \text{ inches.}$$

Standard deviation (yield of corn),

$$\sigma_y = \sqrt{\frac{[y^2] - \frac{[y]^2}{n}}{n}} = \sqrt{\frac{554.96}{28}} = 4.452 \text{ bushels.}$$

$$\text{Coefficient of correlation, } r = \frac{[xy] - \frac{[x][y]}{n}}{n\,\sigma_x\sigma_y} = \frac{3.493}{5.846} = +0.598.$$

$$\text{Probable error of coefficient} = E_r = \pm 0.6745\frac{1-r^2}{\sqrt{n}} = \pm 0.12.$$

That is, $r = +0.60 \pm 0.12$, which magnitudes represent a fairly close order of correlation in problems of this character.

The equation of the straight line defined by the coefficient of correlation and expressing the direct influence of rainfall on the yield of corn as shown by the data analyzed is:

$$y = r\frac{\sigma_y}{\sigma_x}x = 2.027x.$$

The coefficient of x thus found, viz, 2.027, is identical with the one obtained in the direct least square computation, namely b, page 564. This agreement not only checks exactly all the arithmetical work, but *shows the mathematical identity of the two methods of analysis.*

The origin of coordinates for the line given by the equation $y = 2.027x$, is the point defined by the mean value of rainfall, viz, 3.89 inches, and the mean yield, viz, 31.96 bushels. The new axes are dotted in figure 10.

Variation of rainfall above and below the mean should, according to the indications of the data analyzed, be accompanied by corresponding changes of the yield above and below the average yield and in the proportion of 2.03 bushels of corn for each inch of July rainfall.

SUMMARY AND CONCLUSION.

I am indebted to Mr. William G. Reed for an interesting memorandum on the origin and history of the correlation coefficient and a short bibliography of a number of publications dealing with correlation and the theory of statistics. A portion of this is given in the note at the end. Some titles have also been added to the bibliography.

An effort has been made in this paper to outline in a general way the essential principles of the methods of least squares and the theories of statistics and correlation, with reference to their application in the analyses and presentation of climatic data and their utilization in the solution of problems of agricultural meteorology. While a considerable knowledge of mathematics is essential to a complete mastery of all the methods, processes and relations, nevertheless an elementary knowledge and a little study are sufficient to enable any one to carry out the relatively simple routine and systematized calculations that are necessary to bring out all the facts. Examples of these computations have been shown with considerable and seemingly all necessary fullness.

It is hoped the presentation will awaken interest in these valauble agencies and lead to their far greater application in climatic and agricultural studies. Such applications seem to be full of promise, and meteorologists can not afford to neglect, reject, or discredit either the methods or the results of the kind of studies herein considered.

It may seem at first thought that data is inadequate. A closer study indicates that lack of data is not necessarily a serious limitation. A record at a single station may be inadequate, but the meteorologist now has available an enormous mass of statistics which, properly grouped and combined, leaves little to be desired in fixing the general laws of variations and relations.

LITERATURE ON CORRELATION.

"The fundamental theorems of correlation were for the first time and almost exhaustively discussed by A. Bravais [18] more than half a century ago. He deals completely with the correlation of two and three variables. Forty years later Mr. J. D. Hamilton Dickson [19] dealt with a special problem proposed to him by Mr. Galton, and reached on a somewhat narrow basis some of Bravais' results for correlation of two variables. Mr. Galton at the same time introduced an improved notation which may be summed up in the 'Galton function' or coefficient of correlation. This indeed appears in Bravais' work, but a single symbol is not used for it. In 1892 Prof. Edgeworth, also unconscious of Bravais' memoir, dealt in a paper on 'Correlated Averages' with correlation for three variables.[20] He obtained results identical with Bravais', although expressed in terms of 'Galton's functions'".[21]

The following publications contain complete statements of the later developments and bibliographies are given where it is so indicated.

BIBLIOGRAPHY.

Alvord, John W. & Burdick, [Charles S.]. Report to the Franklin County [Ohio] Conservancy District on flood relief for the Scioto valley. Alvord & Burdick, chief engineers. [Columbus, O., 1916.] [xii], 279 p. 65 figs. 8°. (front cover: State of Ohio. The Franklin County Conservancy District . . .) [See pp. 76–85 for "probable frequency of great floods"].

Bravais, A. Analyse mathèmatique sur les probabilités des erreurs de situation d'un point. Acad. des sci., Mémoires presentés par divers savants. Paris, 1846 (2) **9**: 255–332.

Brown, W. The essentials of mental measurement. Cambridge, Univ. Press, 1911. — p. —°.

Comstock, George C. An elementary treatise upon the method of least squares with numerical examples of its application. Ginn, Boston, 1889°. 68 p. 8°.

Davenport, C. B. Statistical methods with special reference to biological variation. 3d rev. ed. Wiley, New York, 1914. viii, 225 p. 12°. [Bibliography on pp. 85–104.]

Edgeworth, F. Y. On correlated averages. Phil. mag., London, 1892 (5) **34**: 190–204.

Elderton, W. Palin. Frequency-curves and correlation. C. & E. Layton, London. [1906]. xiii,172p. 8°. (Published for the Institute of Actuaries.)

Elderton, W. Palin, & Ethel M. Primer of statistics. A. & C. Black, London, 1910. [See p. 55–72.]

Galton, F. Family likeness in stature. Proc., Roy. soc., London. 1886, **40**: 63–73 (appendix).

Great Britain. Meteorological Office. The Computer's handbook. Section V.—Computations related to the theory of probabilities.
1. Errors of observation and variations due to accidental causes with an application to errors of means and normals. By *R. Corless.*
2. Practical application of statistical methods to meteorology. By *W. H. Dines.*
London. 1915. pp. V1–V52. 8°. (M. O., 223. Sect. V.)

Hinrichs, Gustavus Detlef. Rainfall laws, deduced from twenty years of observations. Washington, 1893. 94 p. 16 fig. 8°. (U. S. Weather Bureau.)

Hooker, R. H. An elementary explanation of correlation; illustrated by rainfall and the depth of water in a well. Quart. jour., Roy. met'l. soc., London, 1908, **34**: 277–291.
Correlation of successive observations. Jour., Roy. statistical soc., London, ——, **68**: 676–703.

Horton, Robert E. Supplemental note on frequency of recurrence of Hudson River floods. *In* "The floods of 1913 . . . by Alfred J. Henry." Washington, 1913. 4°. (U. S. Weather Bureau bull. **Z**; W. B. no. 284.) pp. 109–112.

Jacobs. On crop yields, weather. (Indian meteorological department.)

King, W. I. Elements of statistical method. New York, 1912. pp. 197–215.

Köppen, Wladimir. Häufigkeit bestimmter Temperaturen in Berlin, verglichen mit trüben und heiteren Klimaten. Meteorol. Ztschr., Berlin, Juni, 1888, **5**: 230–234.

Merriman, Mansfield. Method of least squares. New York, 1915. 8th ed. viii, 230 p. 8°.

Pearson, Karl. Contributions to the mathematical theory of evolution. London, Royal Society, Philosophical Transactions, Series A, as follows:
(1) On the dissection of frequency curves, 1894, **A185**: 71–110.
(2) Skew variations in homogeneous material, 1895, **A186**: 343–414.
(3) Regression, heredity, and panmixia, 1896, **A187**: 253–318.
(4) On the probable errors of frequency constants and on the influence of random selection on variation and correlation, 1898, **A191**: 229–311.
(5) On the reconstruction of the stature of prehistoric races, 1898, **A192**: 169–244.
(6) Genetic (reproductive) selection; inheritance of fertility in man and of fecundity in thoroughbred race horses, 1899, **A192**: 257–330.
(7) On the correlation of characters not quantitatively measurable, 1900, **A195**: 1–47.
(8) On the inheritance of characters not quantitatively measurable, 1900, **A195**: 75–150.
(9) On the principle of homotyposis and its relation to heredity, to the variability of the individual, and to that of the race, 1901, **A197**: 285–379.
(10) Supplement to a memoir on skew variation, 1901, **A197**: 443–459.
(11) On the influence of natural selection on the variability and correlation of organs, 1902, **A200**: 1–66.
(12) On a generalized theory of alternative inheritance, with special reference to Mendel's Laws, 1904, **A203**: 53–86.
In London, Drapers' Company Research Memoirs, Biometric Series:
(13) On the theory of contingency and its relation to association and normal correlation. Memoir **1**.
(14) On the general theory of skew correlation and non-linear regression. Memoir **2**.
(15) On the mathematical theory of random migration. Memoir **3**, 1906.
(16) On further methods of determining correlation. Memoir **4**, 1907.
(17) (Not published.)
(18) On a novel method of regarding the association of two variates classed solely in alternate categories. Memoir **7**, 1912.

Pearson, Karl. Variation of the egg of the sparrow (*Passer domesticus*). Biometrika, Cambridge, January 1902, **1**: 256–265.
On the systematic fitting of curves to observations and measurements. Biometrika, Cambridge, April 1902, **1**: 265–303; November 1902, **2**: 1–23.

Persons, W. W. The correlation of economic statistics. Quart. publ., Amer. statist. assoc., Boston, 1910: 287–322.

Reed, William Gardner & Tolley, Howard R. Weather as a business risk in farming. Geogr. rev., New York, July 1916, **2**: 48–53. illust. *Abstract in* MONTHLY WEATHER REVIEW, June 1916, **44**: 354. 3 figs.

Sheppard, W. F. New tables of the probability integral. Biometrika, Cambridge, February 1903, **2**: 174–190.

Spillman, W. J., Tolley, H. R., & Reed, W. G. The Average-interval curve and its application to meteorological phenomena. MONTHLY WEATHER REVIEW, April 1915, **44**: 197–200. 2 figs.

[18] Analyse mathèmatique sur les probabilités des erreurs de situation d'un point. Paris, Academie des Sciences, Mémoires présentés par divers savants. Series 2, v. **9**, 1846, pp. 255–332.
[19] *Galton, F.* Family likeness in stature. Proc. Royal Society, London, 1886, v. **40**, Appendix, p. 63–73.
[20] Philosophical Magazine, London, Series 5, v., **34**, 1892, p. 190–204.
[21] *Pearson, Karl.* Philosopical Transactions, Royal Society, London, Series A, v. **187**, 1896, p. 261.

Sprung, A. Ueber die Häufigkeit beobachteter Luft-Temperaturen in ihrer Beziehung zum Mittelwerthe derselben. Meteorol. Ztschr., Berlin, April 1888, **5**: 141–145. 1 fig.

Stevens, James S. Theory of measurements. Van Nostrand Co., New York, 1915. — p. —°.

Walker, Gilbert T. Correlation in seasonal variations of weather, I–VI. Simla, 1909–15. f°. (Indian met'l. dept. Memoirs.)

I. Correlation in seasonal variation of climate. v. **20**, pt. 6, 1909, pp. 122–

II. (A) On the probable error of a coefficient of correlation with a group of factors. v. **21**, pt. 2, 1910, pp. 22–26.
(B) Some applications of statistical methods to seasonal forecasting. v. **21**, pt. 2, 1910, pp. 26–45.

III. On the criterion for the reality of relationships or periodicities. v. **21**, pt. 9, 1914, pp. 13–16.

IV. Sunspots and rainfall. v. **21**, pt. 10, 1915, pp. 17–60.

V. Sunspots and temperature. v. **21**, pt. 11, 1915,p p. 61–90.

VI. Sunspots and pressure. v. **21**, pt. 12, 1915, pp. 91–118.

Weld, Leroy D. The theory of errors and least squares. MacM. Co., New York, 1916. xii, 190 p. 12°.

Yule, G. Udny. Introduction to the theory of statistics. London, 1912. xiii, 376 p. 12°. [Bibliog. pp. 188, 208, 225, and 252.]

INJURY TO VEGETATION RESULTING FROM CLIMATIC CONDITIONS.[1]

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Nearly every winter furnishes conditions which are responsible for more or less injury to vegetation of both native and exotic species. During the past decade a vast amount of damage due to extreme conditions has resulted to vegetation, especially in the northeastern States. There has probably been no period within the memory of living men, or for that matter within the period of exact meteorological records, when damage to vegetation in America has been more extensive than during the past 12 years or since the winter of 1904. Every meteorological factor has its specific influence on vegetation, but since some of these influences are so intimately related to certain types of injury we will [sic] deal only with those concerned in the so-called winter injury. The principal meteorological factors associated with winter-killing and allied phenomena are temperature, soil and air moisture, wind, and light.

Either high or low temperatures or too much or too little soil moisture are conducive to abnormal conditions in plants; also the amount and intensity of light and the movements of the air form important factors in respect to this. Both winds and sunlight have a marked effect on transpiration, even sunlight alone greatly accelerating this process. Therefore, for a correct understanding of the cause underlying injury to vegetation from climatic conditions, it is essential to have some conception of the relative importance of meteorological agencies on plant development and the rôle which they play in regard to susceptibility to various troubles.

Some of the conditions which underlie winter-killing are as follows:

Severe and prolonged cold, causing frost to penetrate to a great depth.

Sudden and severe cold following a prolonged warm spell in the Fall, in which case the wood tissue may be tender and immature.

All conditions which favor a soft growth and immaturity of wood. Various causes may be responsible for this, such as growth in a low, moist soil, too heavy manuring or fertilization, or absence of sufficient sunlight.

General low vitality, caused by insect pests and fungous diseases and by lack of moisture in the soil.

Insufficient soil covering, such as lack of organic matter, light mulching and thin snow covering in winter.

Location in unusually windy and exposed places, etc.

A summer drought followed by copious rains during the Fall is often responsible for the production of immature tissue susceptible to cold.

Plants growing in the drainage of cesspools are likely to be affected by cold owing to the production of unripened wood.

Many of our introduced species are quite tender and are likely to be affected more or less every winter by severe cold. The buds of peach trees are generally affected by cold in the northern States and such plants as the privet, Japanese maples, etc., are affected by ordinary cold. On the other hand, plants that are native further north, such as the Labrador tea, frequently suffer some winter injury in our latitude when grown out of their natural environments. Swamp species transplanted to relatively dry soil suffer more from drought and low winter temperatures than those grown in their normal habitat. Many native plants are winter-killed badly when on the north side of buildings where light is insufficient, because in such situations the wood fails to mature properly. On the other hand, some southern species of plants, such as the magnolias, are more hardy in the north than are some of our native species. Indeed the reason why the magnolias do not grow more abundantly in the north is apparently not connected with temperature requirements.

Some injury to vegetation is generally caused by snow and ice, and this aside from that which occurs from the overloading of branches. The leaves of the lower branches of various conifers are often killed when buried in snow banks and the leaves of arbutus are commonly sun-scorched from exposure to winter snows and ice.

The injuries resulting to vegetation induced by meteorological conditions can be conveniently placed under two different categories, namely, injury to the root system and injury to the aerial portion of the plant, to limbs, branches, and leaves. Injuries which occur to a plant above the surface of the ground and which are associated with meteorological agencies are "frost cracks," "sun-scald," "sun-scorch," and "bronzing."

FROST-CRACKS.

"Frost-cracks" are formed in winter and are due to extreme changes in temperature within the tissues and occur on those portions of the tree where the maximum amount of heat is developed, namely, on the southwest side of the tree. Since the maximum amount of heat derived from sunshine is received generally between 2 and 3 p. m., that portion of a tree-trunk coinciding with the direct rays of the sun at this period is the one most likely to be affected on a day of uniform clearness. Moreover, the location of frost-cracks on a tree coincides with that area giving the minimum electrical resistance, and since the electrical resistance of a tree is proportional to the temperatures of the tissue comprising the same—the lower electrical resistance corresponding with the higher temperatures—that portion of the tree showing the least electrical resistance is most susceptible to frost-crack.

The opening and closing of frost-cracks are very responsive to changes in the meteorological conditions, they being influenced by variation in temperature, moisture, and in barometric conditions. They open more in winter than in summer, more under a dry than under a moist atmosphere, and more during high than during

[1] *Reprinted from* Jour., New York botan. garden, Oct. 1916, No. 202, 17:173–179.

low barometric pressure. Various fruit and shade trees are susceptible to frost-cracks and the principal injury caused is to induce a tendency to bleeding.

SUN-SCALD.

What is called "sun-scald" is associated with severe and abrupt changes in temperature on non-ripened wood. Sun-scald may occur either in the winter or in summer. When coniferous forests are thinned and sunshine is allowed to enter, the exposed trees are likely to suffer from sun-scald. The moose maple, a shade-loving tree, will sun-scald badly in such a thinned forest or whenever transplanted to the open.

Among shade trees the rock maple is one of the most subject to sun-scald; also among fruit trees and shrubs various kinds are affected. Sun-scald is more likely to occur on unpruned apple trees than on pruned ones, or on shaded limbs than on those growing under good light conditions. The shaded limbs on unpruned and neglected apple trees are more likely to be affected by sun-scald owing to the development of unripened wood. Sun-scald may also follow as a result of too intensive sunlight, as, for example, when certain fruit trees are stripped of their foliage in the summer, such as sometimes results from the ravages of the gypsy moth. In such instances the new unripened wood sun-scalds badly.

SUN-SCORCH.

"Sun-scorch," a term applied to the burning of foliage, generally occurs in Summer during periods when the soil is dry, and also is common to evergreens during warm windy days in Spring before the frost is out of the ground. Any defects in the root system which prevent root absorption are likely to give rise to sun-scorch. In the case of evergreens sun-scorch is not infrequently ascribed to winter injury and in fact it may follow winter killing of roots. It may be induced by any cause responsible for a defective root system, such as by winter killing of roots, by drought, or by the use of such fertilizers as have an inhibitory effect on root absorption, etc.

Sun-scorch is common to many trees, particularly the rock maple, and is characterized by a burning of the foliage, which often becomes lacerated when strong winds prevail. Since sun-scorch occurs on the side of the tree coinciding with the direction of the prevailing winds, the particular combinations of meteorological conditions which cause this can readily be determined. In one instance when the wind was blowing at the rate of 72 miles an hour from the northwest during May, at a time when the soil was relatively dry and the leaves exceptionally tender, practically all of the foliage of the rock maples over a large section was sun-scorched on the northwest side of the trees. During another severe dry period in Summer, when the wind was blowing at 80 miles an hour, the white pines in southern New England, which were suffering from a defective root system were sun-scorched.

BRONZING.

"Bronzing" of foliage is a form of sun-scorch characterized by the occurrence of a reddish-brown or bronze color of the leaf. It is produced by lack of soil moisture or defective root absorption during dry, hot periods. In bronzing, the cells farthest removed from the water-conducting tissues of the veins and veinlets of the leaves collapse from want of water, while those nearest to the water-conducting channels may remain alive. These groups of dead cells give the leaf the peculiar color from which this type of sun-scald takes its name. The location of some trees is such that they are subjected to sun-scorch or bronzing during every dry period.

The burning which has occurred so extensively to conifers and evergreens, particularly rhododendrons, during the past Spring comes under the catagory of sun-scorch. This has occurred frequently through many portions of New England. It has been, however, more severe around New York than farther north and has there affected a large variety of evergreen plants.

We are of the opinion that this burning can be traced to the unusually warm period which occurred between January 21 and 29, 1916, at which time the maximum temperature was 60° F. on the 22d and 70° F. on the 27th. This warm spell was responsible for greatly accelerating the vital processes in plants, and the low temperatures which immediately followed it undoubtedly caused the injury. In some instances the leaves were merely scorched and the terminal buds and wood untouched, while in others the burning was more severe and the wood was injured to such an extent that it died back as the warm weather approached.

This burning appears to have been associated with excessive transpiration or exhalation of water from the leaves at a time when the ground was frozen and the water supply to the roots was insufficient, hence causing a wilting and dying of the foliage and, in instances, of much of the younger wood. Some of the hardier rhododendrons appear to have been burned more than those regarded as tender, and plants under trees seem in many cases to have burned more than those exposed to the direct sun. Generally when spring-burning occurs to evergreens it is associated with more or less strong winds and one side shows the burning more than the other. The injury to foliage and wood occurring to plants during the winter does not always show itself immediately, but is bound to be discernible during March or April when the sunshine is more intense and warm strong winds are likely to occur. It is rather difficult to prevent burning to outdoor plants when unusual and extremely abnormal periods occur in mid-winter. Ordinarily most burning occurring to evergreens during the Spring at a time when the frost is in the ground and warm winds prevail, can be prevented if care is taken to handle the plants properly. Where beds are mulched heavily with leaves it is a good idea to remove this mulching from around the base of the plants as soon as there is a tendency for the frost to disappear. This allows sunlight and heat to enter and thaw out the soil around the plants, which in turn gives an opportunity for the roots to absorb water. After the frost is out of the ground the mulching can be replaced.

The removal of the frost and warming of the soil around the roots of plants by any method which will meet the demands of transpiration, or loss of water from the foliage, will prevent sun-scorching of the young wood and foliage.

LASSEN PEAK'S NAME.

U. S. GEOLOGICAL SURVEY PRESS BULLETIN.

[Released October 30, 1916.]

The press dispatches describing the latest eruptions of Lassen Peak show a continued tendency to refer to the volcano as Mount Lassen. *Lassen Peak*, as the most active and interesting volcano in the United States, is specially entitled to be called by its own name, and

[To face p. 571.]

FIG. 1.

FIG. 2.

FIGS. 1 to 5.—Views of the Lassen Peak eruption on Oct. 6, 1915, taken at 10-minute intervals from a point 5 miles distant. (Photos by Chester Mullen.)

FIG. 3.

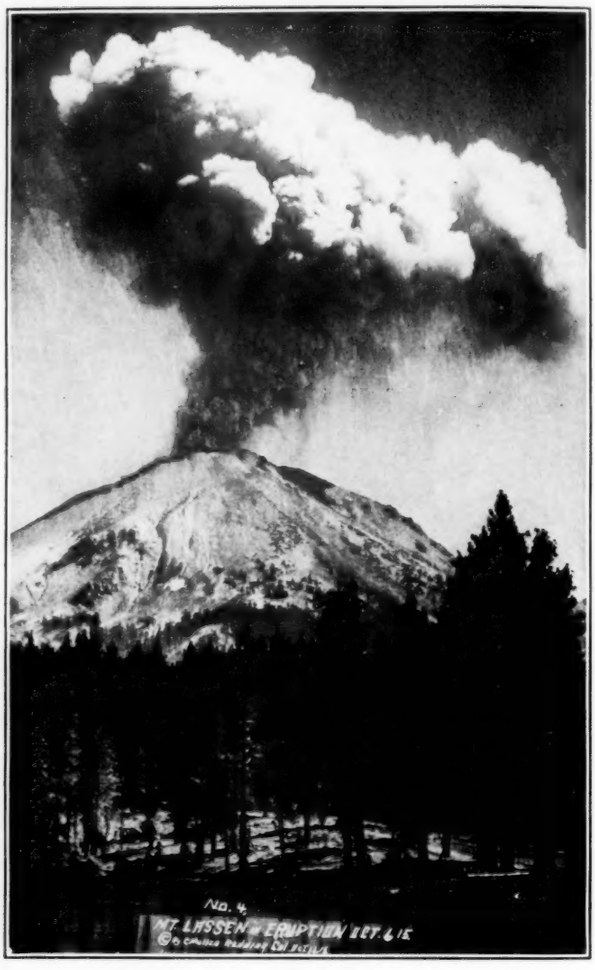


FIG. 4.

FIGS. 1 to 5.—Views of the Lassen Peak eruption on Oct. 6, 1915, taken at 10-minute intervals from a point 5 miles distant. (Photos by Chester Mullen.)

[To face p. 571.]

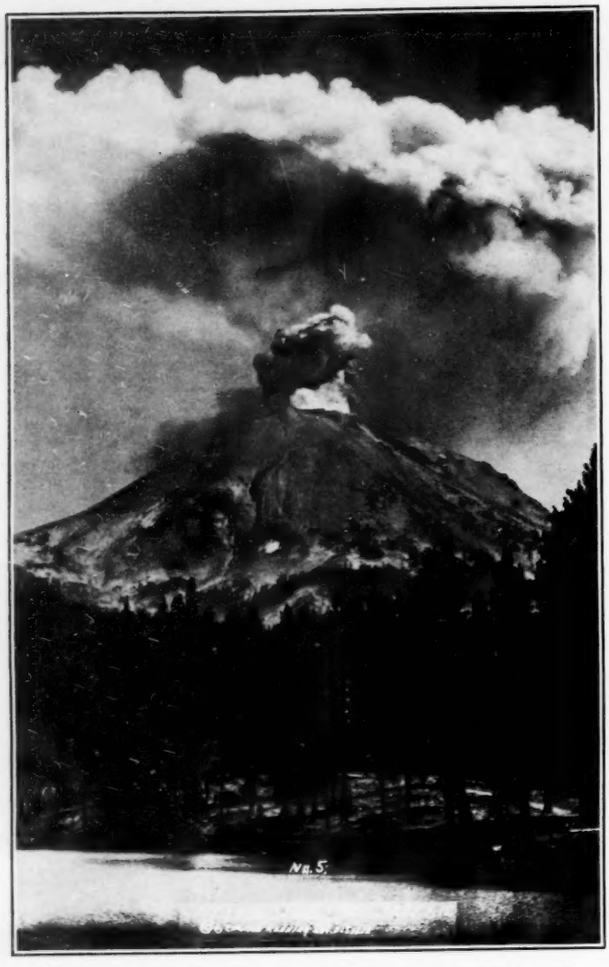


FIG. 5.—Last of series of views of the Lassen Peak eruption on Oct. 6, 1915. (Cf. figures 1–5.)

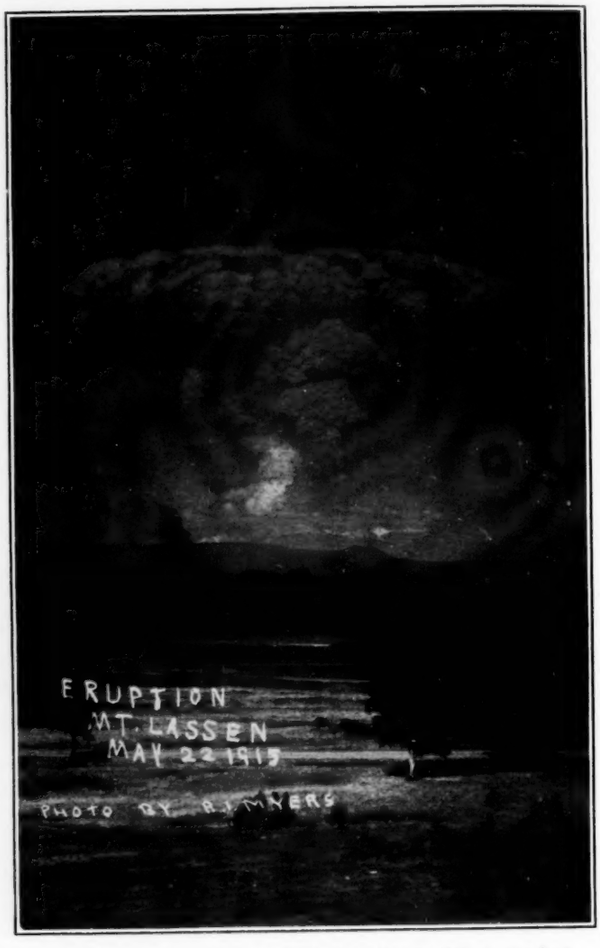


FIG. 6.—The great eruption of Lassen Peak on May 22, 1915, as seen from Anderson, Cal., 50 miles distant. (Photo by R. I. Myers.)

FIG. 7.—A second view of the great eruption of May 22, 1915, as seen from Red Bluff, Cal., shortly after the time represented in figure 6. (Photo by R. E. Stinson.)

[To face p. 571.]

FIG. 8.—Another eruption when the wind increased with the altitude. (Photo by Tuck.)

FIG. 9.—An eruption when the strong wind dispersed the smoke and ash before they could form a vertical column. (Photo by Tuck.)

FIG. 10.—Summit of Lassen Peak, showing the crater formed by the eruption of May, 1914. (Photo on June 20, 1914, by B. F. Loomis.)

acts of Congress and Presidential proclamations in creating and recognizing the Lassen Peak National Forest and Lassen Peak National Monument have given the name *Lassen Peak* a status of high rank in the geologic annals of the Cascade Range. The area has recently been set apart as the Lassen Volcanic National Park.

The name Lassen Peak, according to the United States Geological Survey, *is the only authorized form* on maps, reports, and gazetteers, from the Whitney Geological Survey of California in 1865, to the Geomorphic map of California and Nevada published by the Earthquake Investigation Commission, as well as on the latest map issued by the Forest Service.

Peter Lassen, the sturdy pioneer who guided many an early settler to the sunny lands of the Sacramento, lies buried in a lonely grave in Lassen County. A small, crumbling monument 30 miles from the peak marks his final resting place, but his greater and more enduring monuments are the county and peak named in his honor by a grateful people. The snow-capped Lassen Peak has piloted many an immigrant to the mountain pass.

In the early days of the Pacific Railroad surveys some pious monk called the peak St. Joseph's Mountain, but the names Lassen's Peak and Lassen's Butte soon came into general use. Whitney has shown the inappropriateness of the French term butte, which, translated exactly, means knoll. As Lassen never owned the mountain, in later years the possessive form of the name was dropped, and to correct an illicit tendency to wander from well-established usage the United States Geographic Board, in its decision of October 9, 1915, officially recognized the fact that the name of the mountain was *Lassen Peak*, not Mount Lassen.

AN ERUPTION OF LASSEN PEAK.

By ANDREW H. PALMER, Observer.

[Dated: Weather Bureau, San Francisco, Cal., July 14, 1916.]

Lassen Peak, the only active volcano within the United States, is located in the northeastern part of California, latitude 40° 30′ N., longitude 121° 30′ W., at a distance of 210 miles north-northeast of San Francisco. Rising 10,437 feet above sealevel, it is a conspicuous feature of the landscape. It is the southernmost peak of the Cascade Range, and like most of the mountains forming that range, it is of volcanic origin. While some geographers consider it a part of the Sierra Nevada, its origin and structure, as well as its position, justify its inclusion with the Cascades. These peaks have all been active volcanoes recently, geologically speaking, though measured in terms of years they have long been dormant.[1] Judging from the erosion on the sides of its old cone, Prof. R. S. Holway, of the University of California, believes that Lassen Peak had been quiet for a thousand years preceding its present period of activity. However, Cinder Cone, 10 miles to the northeast, and the Chaos Crags, at the northwest base of Lassen, have been in eruption as recently as 200 years ago.

On May 30, 1914, residents in the vicinity of the Peak were astonished by the appearance of smoke and steam rising from its summit. An investigation made the following day by a ranger in the United States Forest Service revealed the fact that a new crater, 25 by 40 feet, had been formed within the old crater, and that the products of the eruption, consisting of dust and bits of rock, were scattered upon the snow for a distance of 300 feet from the new vent. More eruptions followed, their violence increasing and the size of the crater growing with each successive outburst. The activity culminated with the two great eruptions of May 19 and 22, 1915. While eruptions have continued sporadically ever since, the climax of the present period of activity seems to have been passed. Outbursts continue to become fewer and less violent, much to the disappointment of scientific observers, but greatly to the satisfaction of the residents of the region. A total of about 225 eruptions have been observed. The eruptions during 1916, to July 15, appear to verify the prediction made at the beginning of the year by J. S. Diller, of the United States Geological Survey, that as an active volcano Lassen Peak is again on the decline. Figures 1–5, inclusive, are photographs taken at 10-minute intervals by Mr. Chester Mullen, at a distance of 5 miles from the summit. They show various stages in a typical eruption, that of October 6, 1915.

Certain phases of the present period of Lassen Peak's activity have been investigated and described by authorities in their respective branches. The geological and the physiographical aspects have naturally received the most attention. The physics and the chemistry of these eruptions have been investigated by representatives of the Carnegie Institution of Washington, but their report has not yet been made public. The meteorological and the seismological aspects have apparently been neglected, though many incidental references have been made to them. Certain facts have been observed which are at least of interest, if not of importance, in these two fields. As already indicated, opportunities of this kind are infrequent in the United States, compared with the average life of man, and it is quite probable that another such opportunity will not occur during the present generation. Feeling that certain considerations are worthy of record, the following observations have been collected from all available sources.

METEOROLOGICAL CONSIDERATIONS.

The meteorological aspects of a volcanic eruption are necessarily external to the crater, and are involved principally with the matter emitted. In the case of Lassen Peak certain common forms of matter are known to have been present. The dust and ash consisted entirely of rock fragments, pulverized as by great pressure, and showed no evidence of combustion such as might produce residual cinders. These fragments varied in size from microscopic bits to a mass 15 feet in diameter and weighing more than 60 tons. It appears that steam at high temperature accompanied most of the observed eruptions, and this on condensing formed the visible water vapor which when soiled by the dust particles gave the appearance of smoke. On mixing with the surrounding air this mass cooled, part of the water being precipitated as rain. Following the first eruption, that on May 30, 1914, icicles formed on the projecting rocks on the inner side of the crater. While Diller believes that a considerable volume of water in the form of steam was ejected, the phenomenon was in no sense a geyser, and there is no evidence of surface erosion due to excessive precipitation. Such rainfall must have been very local, perhaps

[1] For historical data relating to volcanic eruptions in the United States consult: *Whitney, J. D.* The United States. Boston, 1889. pp. 113–116.

limited to the slopes of the peak itself. Flames[2] were reported to have been seen at various times, but it is believed that on some of these occasions the reddish color was due to sunshine reflected by clouds. In addition to the dust and water vapor ejected it is probable that there was considerable sulphur in the gaseous state. The latter is characteristic of a volcanic region. Even the fumaroles, which are so common in the great lava fields which form the northeastern part of California and a portion of Oregon and Washington, give off gases containing sulphur fumes. It was therefore to be expected that Lassen Peak should eject sulphur gas. The quantity must have enormous, for on one occasion, when a northerly wind was blowing at the time of an eruption, sulphur fumes were detected 15 miles to the south, and there are no sulphur fumaroles in that direction. Sulphur has been and still is being deposited in a solid state on the inner portions of the crater which are in contact with the charged vapors. That the escaping gases were not poisonous, was shown by the survival of a party of 10 men who were surprised by an eruption while peering into the crater on June 14, 1914.

The temperature of the escaping material is interesting meteorologically because of the effects produced. Observers testify that some of the matter ejected in the great eruption on the night of May 19, 1915, was luminous,[2] a condition requiring a temperature estimated at 600° to 900°C. Part of the superheated gas and ash escaped from beneath the lava cap and did serious damage on the northeast side of the mountain.[3] The sudden melting of the snow produced a flood which destroyed everything in its path of 10 miles in length and exceeding a mile in width. Forest trees were uprooted or broken off at the ground and distributed in parallel rows at the bottom of the slope. Other trees, not destroyed by the rush of water, were seared by the hot blast. The United States Forest Service reported that two forest fires were thus kindled, probably the only cases of such origin which have occurred in the United States since the Forest Service was originated.

The principal fact of meteorological interest associated with an eruption is that related to the wind velocity and direction aloft. Particles freely suspended in the air necessarily travel with the wind, that is, at the same velocity and in the same direction as the surrounding air. An eruption, therefore, produces a graphic cross section of the atmosphere, as far as wind velocity and direction are concerned. Figure 6 is a photograph taken by Mr. R. I. Myers of the eruption of May 22, 1915, the greatest eruption that has occurred. It was taken about 50 minutes after the first evidence of an outburst was noticed.

On this occasion, Mr. N. M. Cunningham, Observer, United States Weather Bureau, at Red Bluff, estimated by means of a nephoscope that the top of the visible column reached at least 20,000 feet above the summit of the mountain, or approximately 6 miles above sea level. The photograph was taken from Anderson, 50 miles distant from the volcano, and the camera was pointed eastward. The top of the smoke column was observed as far distant as Marysville, 80 miles to the south. The mushroom-like structure of the column shows the relatively stagnant condition of the atmosphere, with little or no horizontal movement. At Red Bluff at 5 p. m. on that day the wind was south, with a velocity less than 6 miles per hour. Though it can not be noted from the photograph, the wind aloft had a westerly component. Some of the dust which had risen to the higher levels was carried eastward as far as Winnemucca, Nev., a distance of about 200 miles. On that day the weather of northern California was dominated by a HIGH whose center was off the coast. The cross section is therefore one of an anticyclone. On June 26, 1914, when a slight eruption occurred under conditions of absolute calm, the dust was entirely precipitated within a radius of a mile. It is apparent, therefore, that wind is the principal element which determines the distribution of dust and ash resulting from a volcanic eruption. Moreover, the wind on certain occasions stirred up the dust, ash, and snow on the sides of the peak, and gave a false impression that new craters had been formed. Figure 7 is a photograph taken by Mr. R. E. Stinson in Red Bluff. It is another view of the great eruption of May 22, 1915, and was taken shortly after the photograph shown in figure 6, and after the westerly wind aloft had begun to destroy the gently rounded edges of the column. A second puff of smoke is seen rising in the column, most of that produced in the first outburst having drifted eastward. Figure 8 is a photograph of another eruption, and indicates graphically the increase of wind velocity with height. Figure 9 is a view of still another eruption which occurred when the wind was so strong that the dust and ash were dispersed before they formed a vertical column. It is sometimes stated that wind transports about as much material as do streams. These illustrations show how the finely attenuated products of a volcanic eruption can be carried in suspension by the atmosphere.

Though it is apparent from the photographs that considerable quantities of material were ejected into the atmosphere by the numerous outbursts of Lassen Peak, there has been no widespread production of a volcanic dust veil, or high haze, such as followed the great eruptions of Krakatoa, Mont Pelée, and Katmai. Compared with the latter, the activity of Lassen Peak has been relatively slight. The effects upon the atmosphere have been local, and even the dust veils have been limited to 200 miles. No effect upon the weather was apparent, though the uninformed have attempted to explain various abnormalities in California weather during the past two years as being due to the activity of Lassen Peak. Moreover, there was no evidence of suction or cyclonic effects produced by the drawing in of air laterally to take the place of highly heated air rising vertically, such as is occasionally observed over forest fires. In figure 7 it is apparent that even the cumulus clouds, which form every calm summer afternoon in the mountain regions, were undisturbed by lateral currents.

SEISMOLOGICAL CONSIDERATIONS.

In the popular mind earthquakes and volcanoes are closely associated. However, there is still some disagreement among authorities as to the nature of the relation. While in the Hawaiian Islands volcanoes and earthquakes are intimately associated, the Milne-Omori investigation of 8,300 Japanese earthquakes occurring between 1885 and 1892 showed little relation between earthquakes and volcanoes. Only about 3 per cent of Japanese earthquakes are of volcanic origin. Traditions among the North American Indians associated earth tremors with eruptions of the now dormant Cascade volcanoes. On the other hand, Humboldt found a tradition among the natives of South

[2] As the nearest observers were 20 miles away flames could not be distinguished with any degree of certainty. Much more definite reports, well authenticated, state that flashes of light and cloud glows were visible and that ejected luminous bodies were seen flying through the air.—*J. S. Diller.*

[3] The hot ashes falling on the snow on all sides of the peak melted the snow, as at the head of Lost Creek, producing small flows of mud in all directions down the upper slopes; but *disaster occurred only where* the blast of hot gas was shot from beneath the new lava lid down the northeast slope into the great mass of snow that had accumulated for years, and instantly converted it into a deluge.—*J. S. Diller.*

America to the effect that so long as the volcanoes in their neighborhood were active, no danger from earthquakes need be feared, but if they remained quiescent for a long-continued period severe earthshocks might be anticipated. In a manner the volcano acted as a safety valve, according to the tradition. The presence of an active volcano in California naturally invited an investigation to determine whether or not it was related to earthquakes.

Of the 225 or more observed eruptions of Lassen Peak to date, there is no authentic record of a single sensible earthquake occurring in northern California simultaneously with such an outburst. Press dispatches at various times have announced the occurrence of destructive shocks at the times of these eruptions, but when subsequently investigated none of these reports could be verified. Shortly before the first outburst of Lassen Peak, in May, 1914, a moderate shock occurred in the vicinity of Lassen; two other shocks occurred during 1915. This is about the average frequency, and since none of these occurred on days of eruptions it is believed that they were of tectonic origin, like most California earthquakes. United States forest rangers on duty in the vicinity of Lassen at the times of eruptions heard the escaping steam and the falling stones, but reported no rumbling or subterranean noises, nor did they feel any earthquakes. A letter recently addressed to the United States forest supervisor at Mineral, 10 miles from Lassen Peak, brought the following reply:

> Several very slight earthquake shocks were felt here last summer (1915) and in 1914. They did not, however, occur simultaneously with eruptions of Lassen Peak, and to the best of our knowledge there is no relation between earthquakes and volcanic eruptions in this vicinity. It is true, of course, that the ground in the near vicinity of the mountain is felt to tremble slightly during a violent eruption, but it is doubtful if this is a true earthquake shock.

It is probable that the latter tremors are simply local vibrations similar to those produced by the passage of a railroad train and are therefore not earthquakes in the usual sense.

The cause of the present activity of Lassen Peak is now believed to be the immeasurable pressure of expanding lava rising from below and not the explosive action of steam, as in the case of some other volcanoes. Figure 10 is a photograph of the crater of Lassen Peak taken by Mr. B. F. Loomis on June 20, 1914. Prof. Holway finds it difficult to conceive of steam pressure uplifting so evenly a broken and jagged mass of rock. Diller believes that, although the visible activity is limited to near the summit of the peak, the new lava was forced in a hot, viscous state to the surface, where it spread and overflowed the crater rim. Hot springs and solfataras in the vicinity of the Peak show no evidence of increased activity.

CONCLUSION.

The present cycle of Lassen Peak's activity as a volcano appears to be about complete. While future eruptions will be observed with interest, it is believed that they will be relatively feeble and infrequent. An active volcano in the United States is such a rare phenomenon that it is worthy of careful observation from every point of view. While an active volcano is of primary interest to the geologist and the physiographer, it is of at least secondary importance to the meteorologist and the seismologist. Progress in every field demands the recording of all observations available. Those facts of peculiar interest in meteorology and seismology have been collected and reassembled in the foregoing.

BIBLIOGRAPHY.

Recent articles on the present activity of Lassen Peak have been published by the following:

(1) *W. H. Storms* in Mining and Scientific Press, July 25, 1914.
(2) *R. S. Holway* in University of California Publications in Geography, v. 1, no. 7, August, 1914, pp. 307–330, plates 32–36.
(3) *J. S. Diller* in Bulletin of the Seismological Society of America, v. 4, no. 3, September, 1914.
(4) *R. S. Holway* in Popular Science Monthly, March, 1915.
(5) *J. W. Rushing* in The Dam, July & September, 1915.
(6) *R. S. Holway* in Sunset Magazine, August, 1915.
(7) *J. S. Diller* in Bulletin of the Seismological Society of America, v. 6, no. 1, March, 1916.
(8) *J. S. Diller* in Science, v. 43, no. 1117, May 26, 1916.
(9) *Arthur L. Day*. Geologic history of Lassen Peak.
J. S. Diller. Volcanic phenomena at Lassen Peak.
Abstracts in Journal, Washington Academy of Sciences, June 19, 1916, **6**:404–406.

Its physics and chemistry are now being studied by A. L. Day and E. S. Shepherd, of the Geophysical Laboratory, Carnegie Institution of Washington, and will be described in a forthcoming report.

A NEW METHOD FOR DETERMINING "g" THE ACCELERATION DUE TO GRAVITY.

By HERBERT BELL, Dept. Physics, University of Michigan.

[Read before the American Physical Society, Chicago, Ill., Dec. 2, 1916.]

Consider a compound pendulum consisting of a nut of mass m, movable along a screw rod of mass M, the whole oscillating in a vertical plane about a central axis of suspension O. Denote by MK^2 the inertia of the rod about O, by mk^2 that of the nut about its center of gravity g, and by b_n the distance between O and g as projected along the rod. Suppose further that the point g is not quite collinear with the axis of the rod, but is a small distance u from this line. Then, neglecting the buoyancy and resistance of the air, we have the differential equation of motion

$$(MK^2+mk^2+mu^2+mb_n^2)d^2\theta/dt^2 = -Mhg\sin\theta - mg\,b_n\sin(\theta-\alpha_n) - C\theta,$$

where $\tan\alpha_n = u/b_n$. C is the restoring couple due to the suspension, and h the distance between O and G.

The effect of the air is twofold: (1) on account of buoyancy the restoring couple due to the weight is slightly reduced so that we must replace M and m on the right hand side of our equation by M' and m', slightly smaller quantities; (2) on account of the dragging effect these quantities on the left side must be slightly increased, say, to M'' and m'', we then have

$$(M''K^2+m''k^2+m''u^2+m''b_n^2)d^2\theta/dt^2 = -M'hg\sin\theta - m'gb_n\sin(\theta-\alpha_n) - C\theta.$$

Now the proposal is to take the time of swing T_n for various positions b_n of the nut along the screw. Thus all the constants in this equation except b_n and α_n are absolute constants. C is in any case to be very small in comparison with $M'hg$ or mb_ng.

Let us now simplify this equation by writing new constants in place of groups of constants and assuming that cubes of θ and α_n may be neglected. We thus have after dividing throughout by m''

$$(A'+b_n^2)d^2\theta/dt^2 = -\frac{M'h+m'b_n+c}{m''}g\theta + \frac{m'b_ng\alpha_n}{m''}$$

$$= -\left(B'+\frac{m'}{m''}b_n\right)g\theta + \frac{m'}{m''}g\alpha_nb_n$$

The period of oscillation, T'_n, is therefore given by

$$T'^2_n = \frac{4\pi^2(A'+b_n^2)}{\left(B'+\frac{m'}{m''}b_n\right)g}.$$

There is, however, a further correction if we take into account the logarithmetic decrement λ due to the decreasing amplitude of swing in a resisting medium.

We then have, neglecting λ^4 and higher powers:

$$T_n^2 = \frac{4\pi^2(A'+b_n^2)}{\left(B'+\frac{m'}{m''}b_n\right)g}\left(1+\lambda^2\frac{T'^2_n}{4\pi^2}\right)$$

Multiplying, and writing F_n for $1+\lambda^2\frac{T'^2_n}{4\pi^2}$, sensibly equal to $1+\lambda^2\frac{T_n^2}{4\pi^2}$, and putting $b_n = b_0 + p_n$ we have

$$\left(B'+\frac{m'}{m''}b_0+\frac{m'}{m''}p_n\right)T_n^2 g = 4\pi^2(A'+b_0^2+2b_0p_n+p_n^2)F_n.$$

Now when $n=0$ let $b=b_0$ so that $p_0=0$.
Therefore

$$\left(B'+\frac{m'}{m''}b_0\right)T_0^2 g = 4\pi^2(A'+b_0^2)F_0.$$

Therefore subtracting, we have

$$\left(B'+\frac{m'}{m''}b_0\right)\left(T_n^2-T_0^2\right)g+\frac{m'}{m''}p_nT_n^2g = 4\pi^2(A'+b_0^2)(F_n-F_0)+8\pi^2b_0p_nF_n+4\pi^2p_n^2F_n$$

or

$$B(T_n^2-T_0^2)-8\pi^2b_0p_nF_n+\frac{m'}{m''}p_nT_n^2g-4\pi^2p_n^2F_n=0.$$

Giving n the successive values 1, 2, 3, and eliminating B and b_0 from the resulting three equations we have

$$\begin{vmatrix} T_1^2-T_0^2 & p_1F_1 & \frac{m'}{m''}p_1T_1^2g & -4\pi^2p_1^2F_1 \\ T_2^2-T_0^2 & p_2F_2 & \frac{m'}{m''}p_2T_2^2g & -4\pi^2p_2^2F_2 \\ T_3^2-T_0^2 & p_3F_3 & \frac{m'}{m''}p_3T_3^2g & -4\pi^2p_3^2F_3 \end{vmatrix} = 0$$

or

$$g = \frac{m''}{m'}4\pi^2\begin{vmatrix} T_1^2-T_0^2 & p_1F_1 & p_1^2F_1 \\ T_2^2-T_0^2 & p_2F_2 & p_2^2F_2 \\ T_3^2-T_0^2 & p_3F_3 & p_3^2F_3 \end{vmatrix} \div \begin{vmatrix} T_1^2-T_0^2 & p_1F_1 & p_1T_1^2 \\ T_2^2-T_0^2 & p_2F_2 & p_2T_2^2 \\ T_3^2-T_0^2 & p_3F_3 & p_3T_3^2 \end{vmatrix}$$

g is thus completely determined by the four sets of measurements at p_0, p_1, p_2, p_3, indicated by these determinants provided λ and $\frac{m''}{m'}$ be independently calculable.

As regards the F's, which depend on λ, we can proceed as is usual in the present methods, viz: Observe the rate of fall of amplitude of swing or, better, we can attach an electric mechanism which gives an impulse at the bottom of each swing. In this case $\lambda=0$ and the F's each $=1$.

As regards $\frac{m''}{m'}$: $m''=m(1+f\rho'/\rho)$, where ρ' = density of air, ρ is that of pendulum, and f is some constant of the order of unity; also $m'=m(1-\rho'/\rho)$. Therefore

$$\frac{m''}{m'} = 1+(1+f)\ \rho'/\rho = 1+\beta\rho'$$

where β is constant. Thus

$$g = 4\pi^2(1+\beta\rho')\,M,$$

where M is the ratio of the two determinants.

To take account of the small correction $\beta\rho'$ we must therefore carry out our sets of readings in air of two different densities, say, ρ_1' and ρ_2', $\rho_1'>\rho_2'$. This does not affect the F's (logarithmic decrement). If M_1 and M_2 are the corresponding determinantal values we easily find

$$g = M_2\left(1-\frac{\rho_2'}{\rho'}\right)\left(1-\frac{M_2}{M_1}\frac{\rho_2'}{\rho_1'}\right)^{-1}$$

$$= M_2\left\{1+\frac{M_2-M_1}{M_1}\cdot\frac{\rho_2'}{\rho_1'}+\frac{M_2}{M_1}\cdot\frac{M_2-M_1}{M_1}\left(\frac{\rho_2'}{\rho_1'}\right)^2 + \frac{M_2^2}{M_1^2}\cdot\frac{M_2-M_1}{M_1}\left(\frac{\rho_2'}{\rho_1'}\right)^3+\text{etc.}\right\}$$

Therefore, since M_1 and M_2 are very nearly equal we find that the error in the determination of g due to that in measuring $\frac{\rho_2'}{\rho_1'}$ is given by approximately

$$\delta g = \left(M_2-M_1\right)\left\{1+2\frac{\rho_2'}{\rho_1'}+3\left(\frac{\rho_2'}{\rho_1'}\right)^2++\right\}\delta\left(\frac{\rho_2'}{\rho_1'}\right)$$

$$= \left(M_2-M_1\right)\left(1-\frac{\rho_2'}{\rho_1'}\right)^{-2}\delta\left(\frac{\rho_2'}{\rho_1'}\right).$$

Considering the accuracy with which the barometer can be read this is easily seen to be much less than other and instrumental errors.

The error in g is thus directly proportional to the air density, and by working at two different densities we can find the error, which is in any case a very small quantity.

The suspension should consist of a flat spring very flexible and fastened to a support so rigid that there is no correction needed on that score.

The distances p_n can be measured with great accuracy by any of the modern methods (interference, etc.).

It is essential that the distances p_n be the distances between whole turns of the screw, otherwise the inertias are not constant.

The advantages of the proposal here outlined are: No measurements except of length p_n and time T_n and barometric pressure; no corrections for knife edges or movement of support or rigidity of spring; no calculations of inertia (see *Pellat* in C. R., Nov., 1909).

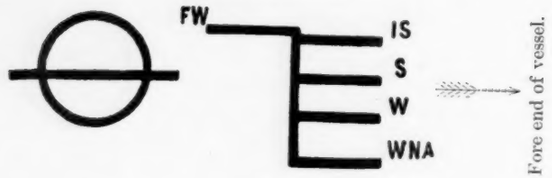
The pendulum should, of course, be made of invar and be worked at a constant temperature.

Any four sets of readings give us a determination. By multiplying these at various positions along the rod we increase the accuracy and detect any error due to inequalities, etc.

[To face p. 575.]

1. STEAMSHIPS.

Starboard Side.



Port Side.

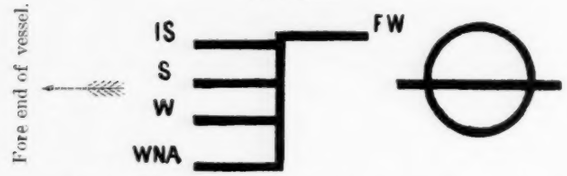


FIG. 1.—Marks and load lines prescribed for merchant steam shipping by the Board of Trade of Great Britain. The letters "I S" show the load line for "Indian Summer." (Photograph of printed regulations of 1899, cited in text.)

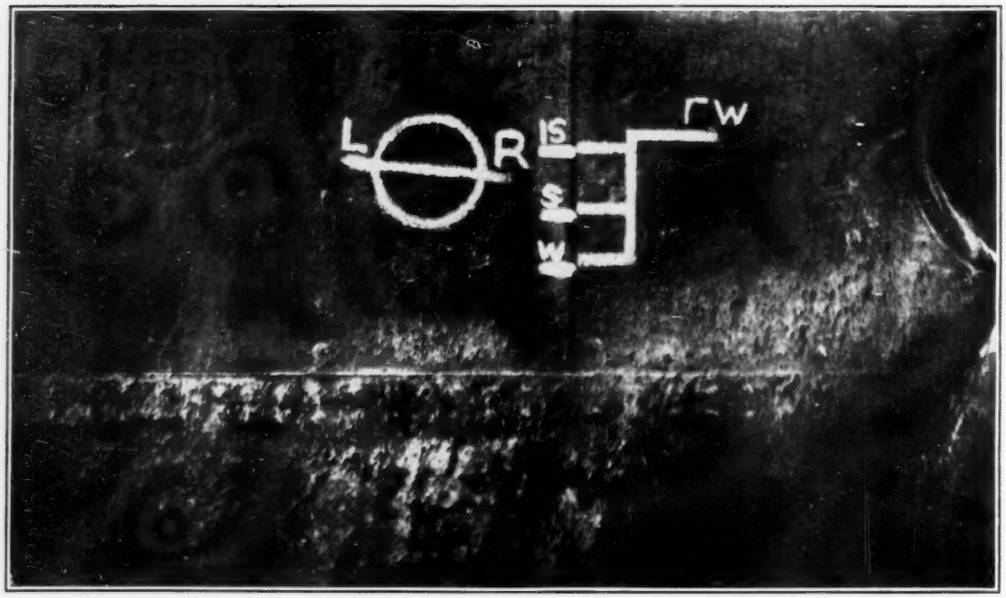


FIG. 2.—Photograph of the starboard marks on the British steamship *Dramatist* (Liverpool). The letters "L R" indicate that the marks were placed under the direction of surveyors of the Committee of Lloyd's Register of British and Foreign Shipping. (Photo by F. A. Carpenter, San Pedro, Cal., Oct. 14, 1916.)

INDIAN SUMMER AND PLIMSOLL'S MARK.

By WILLIAM GARDNER REED.

[Dated: Washington, D. C., Nov. 22, 1916.]

Prof. C. Fitzhugh Talman has directed attention to the use of the term "Indian summer" in connection with the load line marked on British ships ("Plimsoll's Mark").[1] The following is quoted from the regulations of the British Board of Trade regarding load lines:[2]

3. . . . Maximum load lines shall be as follows, and the upper edge of such lines shall respectively indicate:

For fresh water.—The maximum depth to which the vessel can be loaded in fresh water.

For Indian summer.—The maximum depth to which the vessel can be loaded for voyages during the fine season in the Indian seas, between the limits of Suez and Singapore.

For summer.—The maximum depth to which the vessel can be loaded for voyages (other than Indian summer voyages) from European and Mediterranean ports between the months of April and September, both inclusive, and as to voyages in other parts of the world (other than Indian summer voyages) the maximum depth to which the vessel can be loaded during the corresponding or recognized summer months.

For winter.—The maximum depth to which the vessel can be loaded for voyages (other than Indian summer voyages and summer voyages) from European and Mediterranean ports between the months of October and March, both inclusive, and as to voyages in other parts of the world the maximum depth to which the vessel can be loaded during the corresponding or recognized winter months.

For winter (North Atlantic).—The maximum depth to which the vessel can be loaded for voyages to, or from, the Mediterranean, or any European port, from, or to, ports in British North America, or Eastern ports in the United States, North of Cape Hatteras, between the months of October and March, both inclusive.

Such maximum load lines shall be distinguished by initial letters conspicuously marked opposite such horizontal lines as aforesaid, such initial letters being as follows:

F. W.—Fresh water.
I. S.—Indian summer.
S.—Summer.
W.—Winter.
W. N. A.—Winter, North Atlantic.

4. The upper edge of the horizontal line passing through the centre of the disk shall always indicate the maximum summer load line in salt water. The relative positions of the upper edges of the other lines to be used in connection with the disc, with the upper edge of the line passing through the center of the disc (the maximum summer load line), will be indicated in the certificate of approval. * * *

6. Steamships shall be marked on both sides with such of the horizontal lines as aforesaid as are applicable to the nature of their employment, and sailing ships shall be marked on both sides with such of the above-mentioned lines, in addition to the horizontal line passing through the center of the disc, as indicate the maximum load line for fresh water and for North Atlantic winter, but sailing ships engaged solely in the coasting trade shall only be marked, in addition to the horizontal line passing through the center of the disc, with the line indicating the maximum load line in fresh water. * * *

8. The position of the disc and the horizontal line passing through its center, as also the lines to be used in connection with the disc, are shown in the following diagrams [see plate opposite].

The form of application for marking steamers contains the statement: "The vessel is (is not) intended to be employed in the Indian Ocean." In the form of the certificate of approval are the following clauses:

(*a*) * * * the centre of such disc is placed feet inches below the deck line. * * *

(*b*) * * * the position of the lines to be used in connection with the disc shall be as follows:

* * * * *

Maximum load-line in Indian summer.—The upper edge of this line is feet inches above the horizontal line passing through the center of the disc.

* * * * *

The *freeboard for Indian summer* applies to voyages in the fine season in the Indian seas between the limits of Suez and Singapore.

The photograph (fig. 2) shows the load-line mark on the starboard of the British steamship *Dramatist*, of Liverpool, at San Pedro, Cal., October 14, 1916.

The Imperial German Insurance Office in Hamburg approved similar regulations for German ships in 1908. The load-line marking does not include a line for "Indian Summer", but the certificates contain the following statement:

Auf Grund dieser Vorschriften ist die Berechnung des Freibords obigen Dampfers vom Germanischen Lloyd ausgeführt, und sind folgende Resultate ermittelt worden:

* * * * *

Abzug vom Freibord im Indischen und Stillen Ozean während der guten Jahreszeit Meter.

* * * * *

Für Fahrten im Indischen und Stillen Ozean darf das Schiff im Sommer in Seewasser bis zu einer Ladelinie Meter über der Oberkante der Marke S [Sommer] beladen werden.[3]

The recognition of the "fine season" as the time between October and April is shown by the following quotation from a marine insurance policy on cotton from India written in London, December 31, 1868.

[The rate is to be] 50 shillings per cent. [The insurers are] to return 9/6% for sailing between 20th October and 20th April.[4]

WEATHER INSURANCE.

By WILLIAM GARDNER REED.

[Dated: U. S. Office of Farm Management, Sept. 19, 1916.]

INTRODUCTION.

The chance of unfavorable weather conditions has always been regarded as a risk the farmer must assume, and it is obvious that no farm business can be permanently successful if the profits in favorable years are not more than sufficient to offset the losses from frost, drought, and flood. When farming is regarded as a business it is clear that the cost of such losses should be carried as an annual charge against the farm business[1] because it is of exactly the same nature as fire insurance and depreciation of buildings and machinery. That a successful plan for insurance against unfavorable weather has not hitherto been devised is the result of the apparent capriciousness of the weather and also of the fact that weather conditions are generally widespread, e. g., when unusually late Spring or early Fall frosts occur they are apt to be country wide. This prevents the application of the fire insurance theory that country-wide distribution of risks will permit the payment of losses, even of great losses like the Baltimore and the San Francisco

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[1] *Talman, C. F.* Indian Summer. MONTHLY WEATHER REVIEW, January, 1915, 43: 44–45.

[2] *Great Britain, Board of Trade (Marine Department).* Statutory rules and orders, 1899, no. 8. Merchant shipping. Prevention of accidents. Load line. Regulations, dated Jan. 12, 1899, made by the Board of Trade, under the Merchant Shipping Act, 1894 (57 and 58 Vict. c. 60) [London, January, 1899].

[3] The official translation by the British Board of Trade is as follows:
"The freeboard of the above steamer has been calculated by the Germanic Lloyd on the basis of the regulations referred to, and the following results have been obtained:

* * * * *

Deduction from freeboard in the Indian and Pacific Oceans during the fine season meters.

* * * * *

For voyages in the Indian and Pacific Oceans the vessel may be loaded in sea water in Summer up to a load-line meters above the upper edge of the mark S."
See Great Britain, Board of Trade (Marine Department), Circular 1465—Official. Instructions to surveyors. Load Line—German Ships. London. March, 1909.

[4] *Plimsoll, S.* Our seamen. London, 1873. p. 23.

[1] See, for example, "Farm Insurance" in U. S. Dept. Agriculture, Weekly News Letter, Oct. 4, 1916, v. 4, no. 9, p. 7.

fires, from the premiums paid in other parts of the country. Furthermore, until recently it has not been possible to analyze climatic data in such a manner as to permit the determination of the risk involved with crops at different times. For example, the manner in which frosts occur is now known, and therefore it is possible to calculate the proper annual charge to be made against a crop to cover the risk of frost damage.[2] In a like manner the frequency with which any unfavorable weather will occur in the long run may be calculated from the Weather Bureau records; but thus far the Bureau has not compiled and made available the data that may be required to form a basis for every kind of weather insurance. Much of this data is probably comprised within the original records; but a serious effort to evaluate weather insurance risks may create a demand for data not yet collected.

The distribution of risk.

It should be clearly noted than any insurance is simply a device to distribute the risk over so wide a field that the law of chance may operate as a certainty. Accidental occurrences tend to balance one another in the large and, therefore, insurance companies are not subject to the calamaties which would destroy an individual. Insurance against any happening whatever is practicable if the event has been under observation long enough to show the frequency with which it tends to occur.

Inasmuch as the only function of insurance is to balance accidental happenings against each other to eliminate their effect in individual cases, it is obvious that the total cost of properly computed premiums can not be less than the total losses which will occur. Moreover, the premiums must be large enough to carry the cost of doing business. Therefore, the cost of any insurance is somewhat greater than the losses insured against. The advantage of insurance lies in the fact that under scientific rates and properly distributed risks accidental happenings do not occur from the point of view of the company and do occur from that of the policyholder.

For this reason, corporations with widely distributed properties—e. g., railroads—customarily carry their own insurance, depositing with their insurance departments each year money sufficient to cover the annual proportion of the losses experienced in the long run. As there are no charges for advertising or soliciting and only minor charges for adjustment of losses, such corporations can obtain entirely adequate insurance at a lower cost. It is obvious, however, that this is safe only for the larger businesses operating over very wide areas.

Tornado and hail insurance.

Weather insurance of a kind is by no means unknown.[3] Of course, marine insurance has always included losses from the "perils of the sea"[4] in which the weather hazard is of prime importance, and marine insurance is in a large measure insurance against the possible results of dangerous weather. Window and plate glass insurance also involves the risk of breakage by wind and hail, as well as loss due to the entry of rain through broken windows. Hail insurance is common in parts of Europe and has received considerable attention in the central United States and Canada. As carried on here, it is the insurance of a given piece of land for a definite amount of money, usually $6 to $10 per acre west of the Mississippi River, with the possibility of somewhat larger amounts further east. The data on which these rates are based are not known to the writer and the Weather Bureau is not yet prepared to state whether the rates are excessive or inadequate.

The payments are made on the basis of the per cent of damage done to the crop; for example, if a particular acre is insured for $8 against damage by hail, after a hailstorm the number of plants in a hundred feet of row are counted and the percentage of plants damaged is determined; this is done in several parts of the field, and payment is made on the basis of the average of these counts. If the average is 50 per cent damaged, payment on the acre would be $4. Hail insurance premiums range from 8 or 10 per cent in the western part of the High Plains to 4 per cent or less with more liberal policies farther east. In Michigan a State-wide company writes hail insurance which is not definitely assigned to a particular acre, but may be applied to damage done anywhere on the farm. In the Dakotas and western Canada, however, the companies require that the particular acres to which the insurance applies be specified. Mutual hail insurance companies are said to operate successfully with State-wide risks, but not with risks confined to single counties. Such companies generally collect premiums based on the per cent of losses from hail in past years,[5] closing the business at the end of each season in the case of the mutual companies with a dividend or an assessment to make payments balance the losses. Mutual hail policies usually carry a clause permitting the assessment of an amount in addition to the premium equal to the premium paid. For example, if the rate was 6 per cent, an additional 6 per cent or any part of it might be assessed in case of losses heavier than expected or a portion returned if the amount collected for premiums was in excess of the losses and the cost of doing business. Companies insuring crops against hail generally operate independently of other companies. In addition to insurance against damage to crops, hail insurance is also written to cover damage to plate and window glass.

Tornado insurance is common in parts of the United States and Canada, specially in the Middle West. Such insurance generally includes all types of damage done to buildings by violent winds. It is usually written in connection with fire insurance, although in Canada at least one company writes a combined hail and windstorm policy. The rates vary from about half those charged for fire insurance on the same buildings in the Great Plains region to less than a quarter farther east. Tornado in-

[2] *Reed, W. G. & Tolley, H. R.* Weather as a business risk in farming. Geog. Rev., New York, July, 1916. 2:48-53. *Abstract* in MO. WEATHER REV., Washington, June, 1916, 44:354-355.

[3] See International Institute of Agriculture: Miscellaneous information relating to insurance and provident institutions in various countries. Intern. rev. of agric. econ. Rome, 1916, 67:56-61.

[4] "*Perils of the sea* are risks peculiarly incident to navigation and particularly from wind or weather, the state of the ocean, and rocks or shores. Against dangers of this class the carrier does not insure the shipper." (Century Dictionary and Cyclopedia. New York, The Century Company, 1911, 7:4398.)

"The words [*perils of the sea*] obviously embrace all kinds of marine casualties, such as shipwreck, foundering, stranding, &c.; as also every species of damage done to the ship or goods by the violent and immediate action of the wind and waves, as distinct from that included in the ordinary wear and tear of the voyage, or directly referable to the acts and negligence of the assured as its proximate cause." (*Arnould, J.* [Treatise] on the law of marine insurance, 8 ed., E. L. de Hart and R. I. Simey, editors. London, Stevens and Sons, 1909. p. 986.)

"The term *perils of the seas* refers only to fortuitous accidents or casualties of the seas. It does not include the ordinary action of the winds and waves." (Rule 7 "for the construction of ... [Lloyd's S. G.] policy ... under ... ['The Marine Insurance Act, 1906.']," *ibid.* p. 1596.)

[5] As an example of the rates and classes of risks in actual practice, the following "Rates for hail insurance on growing grain crops [in eastern Canada]" may be quoted:

"Rates per $100 of insurance for $2, $3, $4, $5, $6, $7, $8, $9, or $10 per acre: First class, $3; second class, $4; third class, $5; fourth class, $6.

"The class of risk is determined as follows:

"*First class.*—Where hail has not injured or destroyed the crops growing on any part of the land to be described in the application for insurance in the 10 growing seasons last past.

"*Second class.*—Where hail has injured or destroyed the crops growing on any part of the land * * * only once in 10 growing seasons last past.

"*Third class.*—Where hail has injured or destroyed the crops growing on any part of the land * * * only twice in the 10 growing seasons last past.

"*Fourth class.*—Where hail has injured or destroyed the crops growing on any part of the land * * * only three times in the 10 growing seasons last past."

These rates are cited as examples; the Weather Bureau does not indorse them.

surance has been carried on successfully by mutual companies having State-wide risks, but has not been practicable for companies having only county-wide risks, although fire insurance companies are in successful operation within the limits of many single counties.

Practically all fire insurance policies recognize lightning as a probable cause of fire. All these types of weather insurance, however, are based on the fact that these phenomena are relatively so rare that they may be regarded as accidental at any particular locality, although it is recognized that they are more frequent in some places than in others and the rates vary as has been noted to allow for this difference in frequency. But such variation in rates rests on a rather indefinite mathematical basis. The following statement by the eminent French meteorologist Angot [6] is of interest in this connection as showing present conditions in much more densely populated France:

> It will be very important to have numerous exact observations on the falls of hail in France. At the present time the available stations do not enable us to draw charts showing the distribution of hail, that are sufficiently detailed to be valuable. I pointed out this insufficiency more than 10 years ago in studying the storms of 1903, and I have shown that in order to make a complete study of the distribution of hail over a small Department like the Rhone, it would be necessary to have from 280 to 300 stations uniformly distributed. A large Department like the Gironde or the Dordogne would need about 1,000 stations. These numbers suffice to show the difficulties of the problem.

Only the very infrequent occurrence of the phenomenon makes such insurance possible.[7]

The following statement also may be worth considering:

> Anyone who examines the results obtained both by the large mutual societies and by the companies with fixed premiums will be struck by the fluctuations to which both groups are subject.
>
> In 1894, a very favorable year, the net profits rose for both classes to 3,000,000 francs, and the reserve funds to not less than 7,000,000. But in 1897, a bad year, the losses were 1,630,000 francs and the total amount of the reserve funds was about 3,500,000 francs. There was, therefore, in the interval of three years, a difference of nearly 8,000,000 francs.
>
> This comparison of figures is alone sufficient to show the difficulties encountered by hail insurance societies in establishing scientific combinations and reasonable tariffs. It is certain that these questions have not yet been definitely decided, and they will remain a subject for technical consideration until a scientific solution has been arrived at, as only by the investigation of the laws of storms and cyclones can a means of efficacious protection be found against them.
>
> In fact there are no hail insurance tariffs, but some cantons or communes have a splendid system of payments according to their situation, to the exposure of the land, and to the frequency of hailstorms.
>
> The rates are fixed either in accordance with the nature of the insured crops and the frequency of losses in a given period or by contract, according to the amount assured.
>
> (International Institute of Agriculture, monthly bulletin of economic and social intelligence, No. 9, October, 1913, **33:** 41–42.)

"Lloyd's."

Another kind of weather insurance is that written by the London "Lloyd's." This, however, is much in the nature of race-track bookmaking.[8] The chance of any event whatever happening or not happening can be insured at Lloyd's by anyone who is willing to pay the premium; but because of the fact that the only real security of Lloyd's is its immense resources and the wide distribution of its risks over the whole range of insurance and over the whole world as a field[9] the premiums are much higher than they would be if the chances of occurrence were accurately computed.[10] It is customary to insure outdoor events against the occurrence of rain and the premiums are fixed largely on a general knowledge of the frequency of rainy days.

Frequency distributions.

The fundamental mathematical basis of all scientific insurance is the frequency distribution. A study of sufficiently extensive data makes it possible to predict how the events will occur in the long run and the wide distribution of risks makes accidental happenings offset one another. The basis of life insurance is the life table of the actuary, and similar tables are available for fire insurance.

The characteristic distributions of meteorological phenomena have not been studied until recently, because any individual record is too short to furnish the required number of data. Modern statistical methods, however, afford a means of handling these records in the mass and of obtaining results within usable limits of error.[11]

The frequency distributions of Spring and Fall frosts in the United States have been studied,[12] and the chance of killing frost after any date in Spring or before any date in Fall can be determined so accurately that the lack of agreement between calculated and actual occurrences at 569 stations with records varying from 59 to 15 years in length is only about 50 cases in 27,000, or less than 0.2 per cent.

Although the characteristic frequency distribution toward which meteorological phenomena tend is not necessarily the same for all phenomena, the records now available permit the arrangement of these data so that the frequencies can be determined. In the United States the compilation of the data and the study of frequencies has been comprehensive only for frost; preliminary studies of temperature and rainfall data indicate that their respective frequencies also may be determined to a useful degree of accuracy.

The Law of Chance.

All insurance is based on the well-known fact that when a sufficiently large number of happenings are considered there are no accidental occurrences. Any grouping of special cases in one place or at one time will be balanced by a complementary grouping in another place or at another time. The grouping toward which the distribution of the phenomenon tends is a smooth curve when the number of cases is infinite. Studies by various mathematical statisticians have shown that even with as few as 500 occurrences the accidental irregularities tend to balance one another and hence may usually be neg-

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[6] MONTHLY WEATHER REVIEW, March, 1914, **42:** 167.

[7] An insurance company in Canada, is licensed to write "insurance against injury to property caused by cyclones, tornadoes, windstorms, frost or hail, except with respect to propery in transit on water," but its business consists in large part of hail insurance. (See Canada, Superintendent of insurance, Report for 1915. Ottawa, 1916, vol. 1 (Insurance companies other than life), pp. xxxi, clxix, and clxxvi.)

This company has apparently written only tornado (windstorm) and hail (including plate and window glass damage) insurance; its circulars state that rates on frost and forms of policies for insurance against frost damage will be furnished shortly.

[8] This statement is not to be interpreted as derogatory to Lloyd's business, which is entirely legitimate; the rates are determined by competition and in the light of all the information collected by an intelligence system superior to any the world has ever known.

[9] See Martin, F.: "Parliamentary inquiry into marine insurance" *in* History of Lloyd's and of marine insurance in Great Britain, pp. 229–252. Macmillan, London, 1876.

[10] However, the practice at Lloyd's of underwriting risks in parts ("lines") until the whole is covered and the competition resulting from the active trading tends to keep the premiums as low as possible. But the main point stands—this type of insurance at Lloyd's rests on no secure mathematical basis except the compensation of large numbers, immense resources, and widely distributed risks.

[11] *British Meteorological Office.* The computer's handbook (M. O. **223**–Official), Section 5: Computations related to the theory of probabilities.

1. *Corless, R.* Errors of observations and variations due to accidental causes with an application to errors of means and normals.

2. *Dines, W. H.* The practical application of statistical methods to meteorology. London, 1915.

Franklin, W. S. Statistical physics. Science, August 4, 1916 (N. S.) **44:** 158–162.

[12] *Reed, W., G. & Tolley, H. R.* Weather as a business risk in farming. Geogr. rev., New York, July, 1916, **2:** 48–53. Abstract in MO. WEATHER REV., June, 1916, **44:** 354–355.

lected. This fact is fundamental to all determinations of insurance rates, because no insurance company is carrying risks which even approach infinity. If more than a very moderate number of well-distributed risks were necessary to eliminate the accidental, insurance would be far less useful than it is. In weather insurance it is essential only that the risks be so arranged that the rare conditions, even if country wide, will not operate to disturb the financial equilibrium of the company. A study of 569 long records at Weather Bureau stations has shown that there were no unexpected frosts at 414 of the 569 stations (73 per cent) when frost was predicted on the basis of the 10 per cent hazard; and not more than one such frost during the entire record at 94 per cent of the stations.[13] This is not limited to frost conditions but is found to be general in all studies dealing with chance. When once the form of the frequency curve has been adequately ascertained, a number of cases, small when considered from a statistical standpoint, although perhaps large humanly speaking, is sufficient to insure that accidental happenings will so far balance one another that insurance is as safe as if the number of risks were infinite.

Weather and crops.

The control of crops by the weather is obvious and well known. However, weather alone is not responsible for good or poor yields; there are other factors among which the ability and industry of the farmer are of great importance. Weather may be looked upon as a fundamental control, and the necessity of having the right temperature and the right precipitation at the critical times has been clearly shown.[14] Favorable weather even with good soil conditions, excellent cultural methods, and absence of insect and other pests does not necessarily mean high prices, although the yields may be large.[15] Returns from agricultural production are to a very large extent dependent upon the relation of supply to demand. Therefore, when high yields are general prices tend to be low.

But good yields can not be obtained without favorable weather unless some method of preventing damage by the unfavorable weather is adopted (e. g., frost protection). Therefore, a prime requisite of good returns from agriculture is favorable weather; because the fact that prices are high is of little importance to a farmer without a crop to sell. In general favorable weather conditions mean good yields, and prosperity generally follows favorable weather.[16]

The farm business and the weather hazard.

Farm management investigations consider farming from the point of view of the farm as a business unit. When the farm is the unit, the question of high or low yields of particular crops is far from the only thing to be taken into account. The selection of the crops best suited to the region from both climatic and economic points of view has to be considered. This includes the proper arrangement of rotations, the size of the farm, and many other items. It also includes the determination of the proper charges against the farm for interest on the investment in land, buildings, and equipment, depreciation on buildings and machinery, insurance, and taxes; that is, the whole range of charges which go to make up the cost of doing business and which must be added to the product as "burden" if the business is to be successful. Fire insurance has always been regarded as a necessary charge against the farm. Insurance against unfavorable weather has, however, not been carried as such although losses from unfavorable weather are common. This does not mean that the cost of unfavorable weather has not been included in the "burden" assessed against the crops. Heretofore this has been carried mainly in two ways, the attempt to carry the hazard by a large enough profit and loss account or the depreciation of land value to a point where the interest charge will be low enough to permit the capital account to carry the hazard. Needless to say, neither method can be regarded as correct, because the cost of carrying the risk is not accurately determined and the operation of the many other factors prevents the unimpeded operation of the weather hazard.[17]

Therefore, although the farm business can not escape the burden of the weather hazard, the charge for this risk is now unevenly borne. The adequate determination of the chance of unfavorable weather and the proper distribution of the risk by insurance would make it possible to charge the farm business with the correct insurance premium and to substitute a definite charge for an indefinite and expensive hazard.

Weather Insurance Premiums.

Aside from accidental occurrences, the risk of which must be distributed by the operation of the law of large numbers, it is entirely practicable for the individual farmer to carry his own insurance. For example, he may decide to plant his crop at such a time that the chance of safety from spring frost is 9 in 10, that is at a date after which the calculations show the occurrence of killing frost in only 10 years in 100, or 1 in 10 in the long run. If he could be reasonably sure that any given 10 years would follow the average conditions, he would be justified in laying aside one-tenth of the sum he will probably lose in the one unfavorable year. The date on which the chance of killing frost falls to 10 per cent has been determined for over 500 places in the United States. These places are so distributed that a fairly close approximation of the date for almost any place in the country can be determined. A farmer whose loss from an unexpected spring frost would be, say, $1,000 in any one year might plant his crop at the date of 10 per cent risk and put $100 in a savings bank each year. The interest resulting from this investment may be disregarded for the sake of simplicity. At some time during the 10-year period he will lose a crop by spring frost and will then need his $1,000. If this occurs in the tenth year, he will have his money to draw from the bank. If it occurs before the tenth year he will have part of the money available, but he will have to borrow the rest, to be repaid at the rate of $100 a year. But at such a time there will be other losses in the neighborhood and money will be hard to obtain. In addition to this even a casual study of the climatic data shows that no single 10-year period is likely to fulfill the average conditions, so that while the farm business might well afford to carry the risk on the basis of 10 such losses in a century, these losses will almost cer-

[13] *Spillman, W. J., Tolley, H. R., & Reed, W. G.* The average interval curve and its application to meteorological phenomena. MO. WEATHER REV., April, 1916, **44**: 199.

[14] *Smith, J. Warren.* The effect of weather on the yield of corn. MO. WEATHER REV., February, 1914, **42**: 78-92.
The effect of weather upon the yield of potatoes. MO. WEATHER REV., May, 1915, **43**: 222-236.

[15] Sir John Lawes' old maxim "High farming is no cure for low prices," is still true. See *Hall, A. D.* Agriculture after the war. London, John Murray, 1916. p. 105.

[16] *Clayton, H. H.* The influence of rainfall on commerce and politics. Pop. sci. mo., New York, December, 1901, **60**: 158-165.

[17] *See for example* E. J. Russell *in* Nature, London, Aug. 3, 1916, **97**: 460.

tainly be so grouped that an individual farmer could not do so without bankruptcy.

The climatic data show clearly that the chance of frost may be determined with considerable accuracy. An insurance company operating over a field wide enough to eliminate the possibility of bankruptcy on account of simultaneous losses in a whole country or large section of a country would be able to arrange such insurance even if the farmer discountinued his policy when a loss was paid. A company whose operations were confined even to the United States would probably be under the necessity of writing its policies in the form of long time contracts under which premiums would be paid each year and the face value paid when the losses occurred. The premiums would continue through the period of the contract without regard to payments on account of frost occurrence. The period covered by the policy should be equal to that of the average interval between losses—10 years for losses under a 10-per cent risk, 20 years for losses under a 5-per cent risk, etc.

In order to test the practicability of such insurance the frost records of Kansas and Ohio have been analyzed. The numerical data and figures presented are not final values on which insurance may be based; but they indicate the kind of data and approximate values to be derived from existing observational records. It has been assumed that each cooperative station in these States, reporting to the Weather Bureau, was insured for $1,000 in 1906 under a 10-year contract. The premium was assumed at $100 per year and the value of the policy ($1,000) was to be paid whenever a killing frost in Spring occurred on or after a date stated in the policy; this date is 4 days (about the average probable error) later than the date of 10 per cent chance of killing frost.[18] The net results of this insurance appear from Table 1.

The gross profit from the insurance is mainly the result of the 4-day margin of safety. This, together with the interest on the premiums, is probably sufficient to cover the cost of doing business and to provide a small reserve to increase the security. If the reserve becomes too large or too small, the dates should be recalculated with the aid of the constantly accumulating new climatic data, and if it appears to be the result of a peculiar combination of years, the reserve should be held against the future. If, however, it appears that the condition is the result of a margin of safety too large or too small, the margin should be changed to fit the actual conditions.

TABLE 1.—*Net results of the imaginary insurance project computed as an example for Kansas and Ohio, 1906.*

	Premium payments.	Losses.	Reserve and operating account.
Capital			$100,000
1906.			
Ohio	$9,900	$2,000	
Kansas	5,400	11,000	1,700
Balance			98,300
1907.			
Ohio	5,900	22,000	
Kansas	5,400	39,000	49,700
Balance			48,600

[18] *Spillman, W. J., Tolley, H. R., & Reed, W. G.* The average-interval curve and its application to meteorological phenomena. MONTHLY WEATHER REVIEW, April, 1916, **44**: 197-200.
Reed, W. G. The probable growing season. MONTHLY WEATHER REVIEW, September 1916, **44**: 509-512.

TABLE 1.—*Net results of the imaginary insurance project computed as an example for Kansas and Ohio, 1906*—Continued.

	Premium payments.	Losses.	Reserve and operating account.
1908.			
Ohio	5,900	None.	
Kansas	$5,400	$1,000	$10,300
Balance			58,900
1909.			
Ohio	5,900	None.	
Kansas	5,400	None.	11,300
Balance			70,200
1910.			
Ohio	5,900	1,000	
Kansas	5,400	None.	10,300
Balance			80,500
1911.			
Ohio	5,900	None.	
Kansas	5,400	None.	11,300
Balance			91,800
1912.			
Ohio	5,900	7,000	
Kansas	5,400	1,000	3,300
Balance			95,100
1913.			
Ohio	5,900	None.	
Kansas	5,400	8,000	3,300
Balance			98,400
1914.			
Ohio	5,900	None.	
Kansas	5,400	3,000	8,300
Balance			106,700
1915			
Ohio	5,900	2,000	
Kansas	5,400	3,000	6,300
Balance			113,000

When compared with fire insurance the premiums necessary are large. This is because of the difference in the character of the risk. The chance of the loss of any given building by fire is 1 in 300 or 400, while the chance of killing frost after the date named in the policy is 1 in 10.

Practicable insurance against frost is not limited to a 10 per cent risk. Table 2 indicates in a general way the relative range of premiums payable for a policy of $1,000 for a place where the average date of last killing frost in Spring is April 15 and the standard deviation of spring frost dates is 11.7 days.

TABLE 2.—*Type of rate schedule. Fixed payment for loss.*

Rates per $1,000 on Spring frost when average date is Apr. 15 and standard deviation of last killing frost is 11.7 days.]

Face of policy—Payable if killing frost occurs on or after—	Relative annual premium per $1,000
Apr. 20	490
25	334
30	200
May 5	100
10	44
15	17
20	5
25	1

Adjustments for local topography should operate to increase premium for valley bottoms, etc. and to decrease premiums for hillsides.

TABLE 3.—*Type of payment schedule. Fixed premium.*

[Amounts payable for $10 annual premium, when average date Fall frost is Oct. 15 and standard deviation of first killing frost is 12 days.]

When killing frost occurs before—	The relative payment is—
Sept. 15	575
20	225
25	100
30	50
Oct. 5	30
10	20

Adjustments should be made for local topography. Hillsides should be given higher payments, valley bottoms lower payments than those shown.

Table 3 is of similar character for insurance computed in another manner. Here the premium is fixed and the amounts payable if frost occurs before specified dates in the Fall is stated. Each method can be employed for either Spring or Fall frost. Although the application to Spring frost, of the method indicated by Table 3, requires the adoption of a business procedure such as the payment of no losses until after July and no policies written after some date in the early Spring; for example, the average date of last killing frost.

These illustrations show only two of the many possible methods of frost insurance. The frequency distribution of the critical frost dates has been studied in enough detail to enable determinations of the chance of frost at any time to be made for nearly all the agricultural regions of the United States.

Although other phenomena do not show the same frequency distributions as critical frost dates, the distributions for many of these phenomena have been partially investigated and the mathematical studies already completed indicate that the chance of any weather condition at all can be determined with more or less accuracy. Therefore practicable insurance against any unfavorable weather depends solely upon the determination of the hazard and a sufficient number of properly distributed risks.

It may prove possible after weather insurance companies have become well established to write insurance on the basis of crop damage not to exceed the face of the policy. It is not yet practicable to insure a farmer to have a good crop because of the fact that the value of the crop depends on so many causes other than the weather, and insurance of the crop against weather damage rather than insurance against the fact of unfavorable weather will put the better farmers at a disadvantage unless a satisfactory adjustment for the personal and moral elements can be determined.

CONCLUSION.

The farmer has always recognized that the chance of loss must be taken into account and that the returns in favorable years must carry the losses from unfavorable years. The farm business must be operated with a large enough profit and loss margin to cover these losses. The farmer has attempted to cover the risk of loss by diversification and by the selection of planting dates late enough for the chance of frost to be small. The date in each region has been determined by custom and these dates are those determined by the farmers of the region who have not suffered from loss by frost often enough to become bankrupt. These dates of planting rest on an empirical basis as a result of experience. A statistical determination of the risk involved at various times will show how far custom is the result of actual conditions in the region and how far other factors—e. g., tradition—have influenced the dates.

When the risk of loss from unfavorable weather is accurately determined and the crop of each year carries its proper portion of this risk, especially if the risks are widely distributed by insurance, bankruptcy as a result of unseasonable weather is transferred from the class of calamities to that of avoidable losses. In all cases when the chance of loss can be computed in a very large number of cases insurance is the proper method of eliminating the chance of accidental grouping of unfavorable occurrences from bearing too heavily upon the individual. Therefore, the distribution of the risk of crop damage from any condition for which the risk can be computed is a legitimate field for insurance. It is clear that weather hazard can be so determined in many instances and that insurance against the occurrence of killing frost or any unfavorable weather condition may be arranged not as a gambling operation between the farmer and the insurance company but on a sound business basis.

When such insurance has become well established it will be applicable in a much wider field than the simple distribution of the risk of the individual farmer. For example, the insurance rate quoted on a farm will give the purchaser information which will assist him in a determination of the just value; the country banker and storekeeper will be able to insure themselves so that the depression resulting from poor crops will not bear too heavily at any one time; and weather insurance in connection with farm loans may well become as general as fire insurance with loans on buildings and goods or life insurance with personal notes. The fact that the weather hazard is coming into the same class as the fire hazard in that it may be offset by a fixed charge makes possible another step in the series of farm management studies which is developing the business side of farming from a phrase to a reality.

WHAT IS A "GEOCOL"?

In the REVIEW for July, 1916, page 393, was reprinted an article on the rainfall of New South Wales, wherein was employed the geographical term "geocol" when describing the influence of Australia's topography on the rainfall of New South Wales. "Geocol" is not defined in the latest of our large dictionaries, and as the feature is an interesting one the text of the original definition is quoted.[1]

> If the stereogram (or relief map) of New South Wales be examined, it is seen * * * that the main divide is constituted of three well-defined land masses separated by *cols on a gigantic scale*. For these the term *Geocol* is suggested (analogous to Geosyncline) to differentiate these important positive land forms from the ordinary col between two hills.

Concerning the etymology of this word, Taylor has elsewhere[2] stated:

> "Geocol" is admittedly a hybrid word of the same form as peneplain. The prefix geo- is added in the same sense as in geosyncline and geanticline.

[1] *Taylor, Griffith.* A correlation of contour and climate. Proc., Linnean soc. New South Wales, Sydney, 1906, 31:517.

[2] *Taylor, Griffith.* Physiography of eastern Australia. [Melbourne, 1911.] p. 13, footnote. (Australia. Bur. Met'y., Bull. no. 8. 4°.)

In the first paper cited Mr. Taylor outlines the manner in which he finds the Cassilis geocol to affect temperature distribution, rainfall distribution, and even the movements of HIGHS and LOWS. The map of isotherms shows that these tend to form a saddle at the geocol, which is not unlike the saddle in the isohypses; similarly there is a saddle in the isohyets at the geocol; again the geocol forms a great breach in the mountainous barrier of the Blue Mountains—New England massif, a breach toward and through which HIGHS sometimes are guided by the Blue Mountains. Such a HIGH has a Southerly Burster associated with it (pp. 523–526, and his plates xlv–xlviii.) The Cassilis geocol seems also to have served as a gateway for the eastward migration of plant forms which are otherwise confined to the western side of the divide.

The study of topographic influence on weather and climate which Mr. Taylor has carried through for eastern Australia, notably for New South Wales, suggests interesting relations which might well form the subject of some studies by a college or other student of the weather of the United States. Perhaps such a study seems too detailed for the American; but such detailed knowledge is just what the actual or prospective resident of any place needs and demands of those to whom he should turn for information.—C. A., jr.

A CYCLONE IN PERSPECTIVE.

Since 1907 Mr. Merton Leonard Fuller, Local Forecaster at the Weather Bureau office in Peoria, Ill., has been using a very graphic representation of a cyclone passing over the United States, to help his classes in meteorology gain a livelier idea of the processes of our weather. This perspective view he has recently published privately elsewhere,[1] and now permits us to reproduce in the accompanying figure for the benefit of others who also may find the device useful in teaching.

The storm represented here is one that moved from southern California northeastward across Nebraska to the valley of the St. Lawrence River between December 4 and 6, 1906. (See this REVIEW, December, 1906, Chart III, track III.) While the diagram does not show the track, but represents horizontal and vertical conditions as they probably appeared at 8 a. m., December 5, 1906, the course would have appeared as a slightly curved line from about where stands the "F" of "Pacific" to the center of the isobar of 29.6 inches as shown. Of course, every reader of the figure will always bear in mind that the vertical scale is greatly exaggerated and that the storm is very much thinner than as here shown.

[1] *Barber, F. D., & others.* First course in general science. New York, 1916. 8°. p. 263, figure 188.

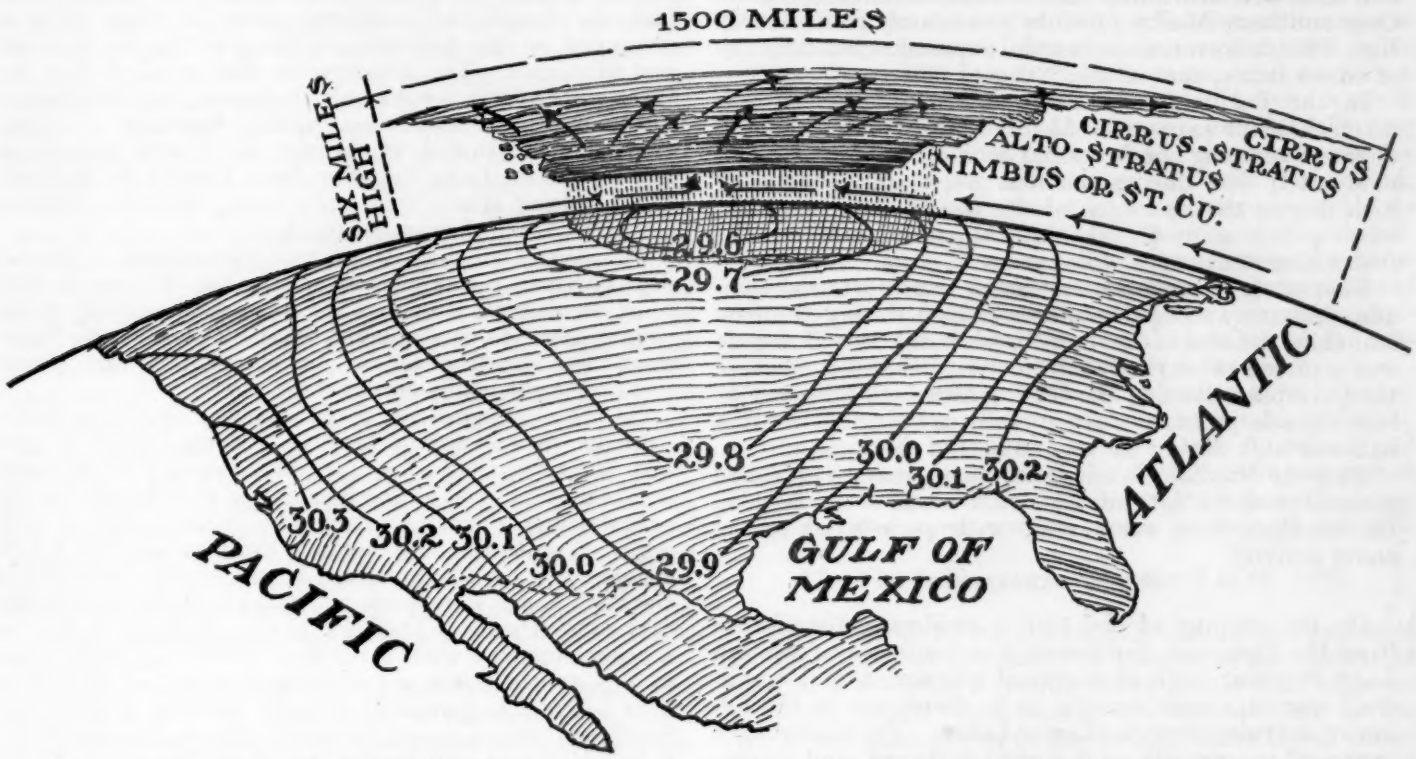


FIG. 1.—Perspective and cross section of the storm of December 4–6, 1906, when central at about Omaha, Nebr., 8 a. m. (75th mer.), on December 5. (M. L. Fuller.)

SECTION III.—FORECASTS.

FORECASTS AND WARNINGS FOR OCTOBER, 1916.

By H. C. FRANKENFIELD, Supervising Forecaster.

GENERAL PRESSURE DISTRIBUTION OVER THE UNITED STATES AND CANADA, INCLUDING THE HAWAIIAN AND ALEUTIAN ISLANDS, ALASKA, AND THE MIDDLE ATLANTIC OCEAN.

Pressure was moderately low over the Hawaiian Islands from October 4 to 12, inclusive. Otherwise it was nearly normal.

Over the Aleutians pressure was generally low during the first half of the month, moderately high for two days, moderately low for six days, and quite high during the last week of the month, with a pronounced crest on the 25th.

Over northern Alaska low pressure predominated, with the greatest negative departure from the normal on the 3d and 4th. There was one principal system of high pressure that extended over Alaska generally on the 16th and 17th, and there were also minor ones on the 24th, 26th, and 30th, Over southern Alaska pressure was almost continuously high, with, however, an occasional depression, but only one of consequence, that of the 28th and 29th.

In the Pacific States the pressure distribution was much the same as over the Aleutians, but to a less marked degree, averaging above normal between the 6th and 23d, moderately low during the first week and moderately high during the last week of the month until the 29th, when a depression from Alaska appeared, marking the first winter storm type of the present season.

East of the Pacific States, except over northeast Canada, pressure averaged moderately high during the first and third decades of the month, while the second decade was a period of marked storm activity that also covered the Caribbean Sea and the Gulf of Mexico. Over northeast Canada pressure was generally low during the first half and high during the second half of the month.

Over the Middle Atlantic Ocean high pressure prevailed generally north of latitude 30°, while south of this parallel the tendency was subnormal, with periods of severe storm activity.

STORM WARNINGS.

On the evening of the 12th a moderate disturbance from the Canadian Northwest was central over eastern Lake Superior, with an eastward movement, and small-craft warnings were ordered to be displayed on the following morning over the Lower Lakes. The disturbance increased in intensity as it moved eastward, and moderate southwest to northwest gales occurred during the 13th over Lake Ontario and central and eastern Lake Erie. On the morning of the 13th, with the disturbance central over Ontario, southwest storm warnings were ordered ftom Delaware Breakwater to Eastport, and at 2:30 p. m. extended southward to Hatteras, N. C. Fresh to strong southwest to northwest gales occurred generally, diminishing after the morning of the 14th. At this time another Canadian Northwest disturbance was a short distance northwest of Lake Superior, and as the gradient was quite sharp to the southward small-craft warnings were accordingly ordered for the northern Upper Lakes region. Fresh to strong southwest winds occurred during the day.

The rapid succession of northwest disturbances continued, and on the morning of the 16th a low-pressure system of marked character was central over western Lake Superior, after having greatly increased in intensity and rate of progression since the preceding evening. Northwest and southwest warnings were at once ordered for the Upper Lakes, and at 2:30 p. m. southwest warnings were also ordered for the Lower Lakes. Moderate to fresh west and northwest gales occurred during the day over the Upper Lakes, continuing during the night and extending throughout the Lower Lakes region. At 8 p. m. of the 16th the storm was central over Georgian Bay, with undiminished intensity, and at 9:30 p. m. southwest storm warnings were ordered along the Atlantic coast from Delaware Breakwater to Eastport. Fresh to strong westerly gales occurred on the following day. At 8 p. m. October 17 there was another Canadian Northwest disturbance of marked character on the weather map, but this one had moved in a more southeasterly direction, and was thus central over western South Dakota. Small-craft warnings were therefore ordered displayed on the following morning on Lakes Superior and Michigan. The disturbance dissipated during the 18th, and the winds were only moderate, but, as pressure to the westward was rising rapidly, warnings of strong and colder northwest winds with snow were ordered at 5:30 p. m. on Lake Superior from Duluth to Ashland. The resulting winds were only fresh, although freezing temperatures and snow occurred.

The next Canadian Northwest disturbance appeared over northern Saskatchewan during the 23d, and at 9:30 p. m. small-craft warnings for fresh southeasterly winds were ordered to be displayed on the 24th on Lake Superior. The disturbance did not develop to any extent and only light winds occurred.

On the morning of the 21st there were evidences that a disturbance was approaching the extreme northern portion of Lower California. It spread slowly to the east-northeastward, and on the morning of the 23d was central over Arizona, with an arm of moderate depression extending over southwest Oklahoma. Pressure was quite high immediately to the northward, and on the morning of the 24th there were some indications of the dissipation of the disturbance. During that day, however, there was a redevelopment with a northeastward movement, and at 8 p. m. there was a well-defined center of depression over Iowa that promised a rapid increase in intensity. Southeast storm warnings were therefore ordered for Lakes Michigan and Huron, and from Detroit to Cleveland, the winds to become strong easterly, and to shift to northwest on the night of the 25th. On the morning of the 25th the storm was central over north Lake Michigan, with increasing southeast winds, and southwest warnings were ordered for the balance of the Lakes except western Superior. As pressure was falling rapidly to the eastward, southeast warnings, to be changed to southwest at sunset, were ordered on the Atlantic coast from Portland, Me., to Delaware Breakwater, Del. Special reports at noon of the 25th indicated strong northwest winds over west Lake Superior, and northwest warnings were ordered accordingly. Strong winds occurred over the entire district where warnings were displayed, but

none after the morning of the 26th, and the warnings on the Atlantic coast were lowered at 10 a. m. of that date.

On the morning of the 28th there was a slight depression over eastern Nebraska, with a northeastward tendency, and small-craft warnings for fresh southerly winds were ordered for the Upper Lakes. Although there was but little further development of the disturbance, fresh winds occurred as forecast.

FROST WARNINGS.

The frost warnings that had been issued on the morning of September 30 for the section from the Ohio Valley and Lower Lakes region eastward, were excellently verified on the morning of October 1, when marked high pressure prevailed over the northeastern quarter of the country, with the crest over the lower St. Lawrence Valley. As there was no prospect of an immediate change in the conditions, the warnings were repeated for the Atlantic States as far south as Virginia, and frosts again occurred as forecast on the following morning with light touches also in the mountain districts of Tennessee and North Carolina. Owing to cloud formation local warnings on the morning of the 2d were only partially verified on the 3d. On the morning of the 5th frost warnings for north and west Michigan were issued, following the passage of a moderate depression, but although the succeeding HIGH was of considerable magnitude frost occurred in Upper Michigan only. The still more moderate depression of the 8th was followed by a high pressure system of more marked character, with its crest farther to the northward than on the 5th, and warnings were issued for heavy frost in Michigan and light frosts in the north portions of Indiana and Ohio. Midday special observations indicated general clearing of the weather, and the warnings were therefore extended into northern and western Kentucky, southern Indiana, southern Ohio, western Pennsylvania, and western New York. Frosts occurred as forecast on the following morning (Oct. 10) except in Kentucky. Pressure was then generally high east of the Rocky Mountains, and frost warnings were issued for all portions of the Washington forecast district, except Florida and the southern portions of the East Gulf States. Heavy frost was forecast for the central and northern districts. Again frosts occurred as forecast as far south as Tennessee and North Carolina, but there was none to the southward owing to cloudiness induced by the low pressure over the Caribbean Sea and eastern Gulf of Mexico. The local frosts that occurred on the morning of the 12th for the Middle Atlantic States were also forecast, but not the light frosts that occurred in the southern Appalachians.

No frosts of consequence occurred from the 13th to the 20th, inclusive. On the morning of the latter date, when the great West Indian storm was central over south Lake Michigan, high pressure with killing frosts prevailed over the Southwest, and frost warnings were therefore ordered for the southern states generally, except along the Atlantic coast and in Florida (ordered for extreme northwest Florida at 1:50 p. m.), and warnings of freezing temperatures in the Ohio Valley and Tennesseee. On the morning of the 21st conditions were almost exactly as had been forecast, the frost line extending to Pensacola, Fla., and the freezing temperature line into western Tennessee. Cold high pressure still continued in the Southwest, and general frost warnings were again issued, the frosts to extend on the morning of the 22d to the South Atlantic coast, except in central and southern Florida. These forecasts were verified as were also those made on the morning of the 23d for the Atlantic States as far south as Georgia.

On October 25 another severe storm was passing eastward over the Upper Lake Region, with a following high-pressure system of great extent to the westward and southwestward, but with another depression approaching from the Canadian Northwest. On the morning of the 26th the crest of the high-pressure system was over the western Gulf States, and frost warnings were ordered from Maryland southwestward into central Mississippi. Frosts occurred on the following morning as forecast.

During the month frost warnings were issued as required for the cranberry districts of Massachusetts and New Jersey. Frosts occurred uniformly as forecast, and no frosts occurred without previous warning having been given.

WEST INDIAN STORMS.

Conditions were very active during much of the month over the Caribbean Sea, the West Indies, and that portion of the Atlantic Ocean south of latitude 35°, and several storms of hurricane character developed. Only one of these, however, reached the United States, and that one by way of the middle Gulf coast, an unusual course for the season of the year.

The first information of definite storm formation was obtained on the evening of October 2, when radio reports indicated the presence of a disturbance about 200 miles off the Georgia or South Carolina coast, and northeast storm warnings were immediately ordered from Norfolk to Charleston. More complete reports on the following morning indicated that center of the storm was off the Florida coast, farther south than had been first stated, and at 1 p. m. the northeast warnings were extended to Tybee Island and Savannah, Ga. At 8 p. m. October 3, there were some evidences of a further increase in the storm intensity, and the northeast warnings were continued from Norfolk to Charleston, and on the following morning at Tybee Island and Savannah, when the storm center was apparently a short distance off the Georgia coast. Up to this time strong northeast gales had been reported off the South Atlantic coast, and during the 4th moderate northeast gales occurred on the South Carolina and Georgia coast. By 8 p. m. of the 4th the storm had passed inland to northern Florida with greatly diminished energy, and the storm warnings were accordingly lowered.

The West Indian storm of October 7 to 12, 1916.

After a few days' respite another disturbance appeared in the vicinity of the Island of Dominica, the barometer at 8 a. m. October 7 reading 29.84 inches with calm air and rain falling. Notification was sent at once to the Windward Islands and to the United States Naval Radio Service, and special observations called for. Nothing of value was received during the day, but on the morning of the 8th it was apparent that the disturbance was near and east of Porto Rico and moving northwestward or northward. Advices to this effect were sent to West Indian points and to Weather Bureau stations on the Atlantic and Gulf coast and broadcast by United States Naval Radio. No further reports were received until the morning of the 9th, when the regular reports showed the storm to be still east of Porto Rico. Special evening reports afforded the first definite information as to the location of the storm center. These reports were to the effect that the storm center had passed over the Danish

West Indies, Santa Cruz reporting pressure of 29.42 inches at 3 p. m., with a gale, and St. Thomas, 29.26 inches at 6 p. m. This information was immediately given wide distribution over the water and along the coasts, and shipping warned to exercise great caution. By the morning of the 10th the storm had recurved slightly and had passed to the northeastward of Porto Rico. Nothing further was heard from the storm until the captain of the barque *Bellas* reported by mail that he had encountered it, in the form of a severe hurricane with southeast to southwest gales, on October 12 in latitude 27° 40′ N., longitude 62° 20′ W.

The storm of October 9 to 19, 1916.

The point of origin of the next disturbance is uncertain. After the passage of the previous storm, pressure continued to fall over the Caribbean, especially to the southward of Jamaica, and on the morning of the 11th there were observed the first evidences of distinct cyclonic circulation with a center apparently a short distance south of Jamaica. The disturbance did not then appear to be of severe character, and no reports that were received later tended to disprove this contention. By the morning of the 13th the center of disturbance had apparently moved to the western Caribbean, probably to about latitude 16° 30′ N. and longitude 78° W. Advisory warnings were then distributed and special reports called for. During the succeeding 24 hours the storm appeared to greatly increase in intensity and at 11:30 a. m. passed very close to Swan Island, the barometer reading at that place being 28.94 inches, with the wind blowing with hurricane force from the north. At 9 a. m. the radio apparatus was put out of commission by the storm and it became impossible to send any further reports.

Wind direction and force, weather, and barometer readings at Swan Island are given in Table 1.

TABLE 1.—*Observations at Swan Island.*

Date.	Barometer.	Wind.		Weather.
		Direction.	Force.	
1916.	*Inches.*		*0—12.*	
Oct. 13, 8 a. m.	29.74	ne.	1	Cloudy.
Oct. 13, 1:40 p. m.	29.70	n.	2	Do.
Oct. 13, 3 p. m.	29.70	n.		Do.
Oct. 14, 6 a. m.	29.37	n.	10	Raining.
Oct. 14, 7 a. m.	29.36	n.	10	Do.
Oct. 14, 8 a. m.	29.26	n.	10	Do.
Oct. 14, 9 a. m.	29.20	n.	12	Do.
Oct. 14, 11:30 a. m.	28.94	n.	12	Do.
Oct. 14, 12:30 p. m.	29.03	e.	12	Do.
Oct. 14, 1 p. m.	29.04	e.	12	Do.
Oct. 14, 8 p. m.	29.32	e.	12	Do.
Oct. 15, 8 a. m.	29.74	se.	8	Do.

The observer at Swan Island reported that the wind blew at the rate of at least 100 miles an hour at times and with hurricane force from 8 a. m. of the 14th until 3 a. m. of the 15th.

Warnings were, of course, immediately sent out broadcast, and all shipping warned to take every precaution for safety. No evening reports were received during the 14th, but the warnings of the morning were repeated, and again on the afternoon and evening of the 15th, the center at the latter time being placed not far south of the Yucatan Channel. On the morning of the 16th the storm center was apparently crossing the northern portion of the Yucatan Peninsula, moving northwestward or northward, and warning advices were again issued morning and evening. During the night of the 16th–17th the storm passed into the Gulf of Mexico, and at 8 a. m. of the 17th was apparently central at about latitude 24° N., longitude 88° 30′ W. Northeast warnings were then ordered on the Gulf coast from Carrabelle, Fla., to Bay St. Louis, Miss. All interested were advised to take every precaution for safety, and all shipping advised to remain in port. These warnings were repeated in the afternoon and again at night. A late radio report from the steamship *El Rio* showed that at 1 a. m. of the 18th the storm center was not very far from latitude 27° N., longitude 89° W., with a barometer reading of 28.98 inches and a heavy easterly gale. By 8 a. m. of the 18th the storm center was in the vicinity of Fort Morgan, Ala., with the tide 2 feet above normal at Pensacola, Fla. Hurricane warnings were then ordered displayed from Apalachicola, Fla., to New Orleans, La.; northeast storm warnings were also ordered along the Atlantic coast from Savannah to Cape Henry, and special warnings of approaching destructive gales were sent to interior points in northwestern Florida, western Georgia, Alabama, and Mississippi, with instructions to distribute the information widely. The storm then moved inland, the center passing almost directly over the city of Pensacola, Fla., at 10:30 a. m., 75th meridian time, when the barometer read 28.76 inches, with a wind of 48 miles an hour from the southeast and a tide 3 feet above normal height. At 10:12 a. m. the wind reached a 5-minute velocity of 114 miles an hour from the southeast, with an extreme velocity of 120 miles an hour from the southeast at 10:13 a. m., the anemometer going down at 10:14 a. m. After the lull attending the passage of the storm center the wind again increased from the west, reaching an estimated velocity of 120 miles an hour. After 11 a. m. the wind subsided to less than a gale.

Figure 1 is a reproduction of the automatic records of pressure, wind direction, and wind velocity at Pensacola during the passage of the storm.

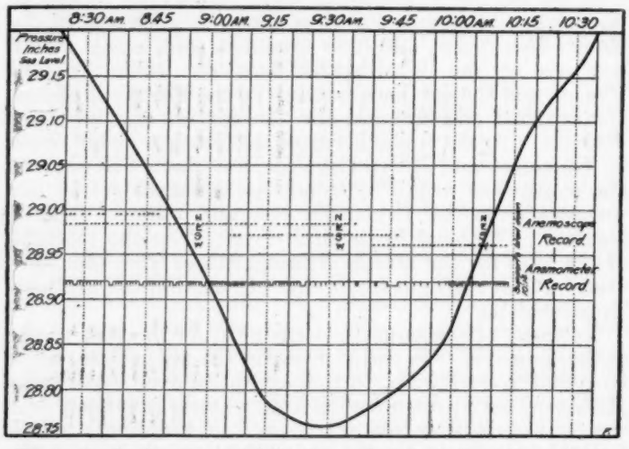


FIG. 1.—Graphs of pressure, wind direction, and wind velocity at Pensacola, Fla., during passage of hurricane of October 18, 1916. Anemoscope records dots at 1-minute intervals; anemometer records a tooth for every mile of wind, the pen is held down for the tenth mile.

At Mobile the lowest pressure was 29.22 inches at 8:35 a. m., 0.46 inch higher than at Pensacola. The wind velocity, however, was 115 miles an hour from the east at 8:25 a. m., practically the same velocity as at Pensacola, with an extreme velocity of 128 miles an hour from the east at 8:28 a. m., somewhat higher than at Pensacola.

Precipitation was not excessive in the vicinity of the storm center, but was torrential some distance away, both

to eastward and westward, Burrwood, La., reporting 11.88 inches during the 24 hours ending at 8 a. m., October 18. The storm center moved rapidly inland and the hurricane warnings were soon changed to storm northwest, the latter being lowered at 9 p. m.

The storm did little damage, comparatively speaking, as ample precautions had been taken on all sides, and furthermore, the storm moved so rapidly that its force in any one locality was soon spent. There was, however, one shipping casualty in the extreme western Caribbean with the loss of some 20 lives.

On the morning of October 15 the storm was central over Indiana, with a lowest reported pressure of 29.58 inches, and with marked high pressure and very steep gradients both to the northeastward and northwestward. Northeast and northwest warnings for strong winds and rain turning to snow were then ordered on the Upper Lakes, and southeast warnings for southerly gales on the Lower Lakes and on the Atlantic Coast from Hatteras to Eastport. Small craft warnings were also ordered from Wilmington, N. C., to Savannah, Ga. At 8 p. m., October 19, the disturbance covered the Upper Mississippi Valley and the Lake Region with indefinite formation, and with falling pressure to the northwestward. Warnings were therefore lowered from Cleveland, Ohio, westward, but were again hoisted on the following morning when the storm showed a remarkable redevelopment with a single center over extreme northeast Illinois, but as yet without strong winds. During the 19th southerly gales prevailed along the Middle Atlantic and New England coasts, and strong gales on the 20th over the Lower Lakes, with several casualties to shipping, attended by considerable loss of life. Over the Upper Lakes the winds were not so violent, and on the morning of the 21st the storm center had passed northeastward beyond the Province of Ontario.

Owing to the redevelopment of the storm, southwest warnings were again ordered at 3 p. m. of the 20th from Hatteras to Boston, and extended to Eastport at 10 p. m. Moderate southerly gales occurred as forecasted.

The subtropical disturbance of October 21, 1916.

On October 21 the pressure was again falling over the West Indies and the adjacent waters with a center of disturbance apparently in the vicinity of the western Bahamas. As the unsettled conditions persisted on the morning of the 23d, it was thought best to order northeast storm warnings from Fort Monroe, Va., to Charleston, S. C.. As anticipated, the warnings were followed by fresh northerly gales that, however, did not quite extend to the coast stations. At 10 p. m., October 23, the warnings were extended to Jacksonville, radio reports indicating the necessity therefor. As there was little apparent change on the morning of the 24th, the northeast warnings were continued, as did also the gales, but by the morning of the 25th the winds had subsided, and the warnings were lowered.

Low pressure, however, persisted in Florida, the Antilles, and the Caribbean, and continued until the end of the month, necessitating frequent cautionary advices to shipping. While there was no definite center of disturbance located, moderate gales occurred at times over the western Caribbean.

DISTRICT WARNINGS DURING OCTOBER.

Chicago, Ill., forecast district—Following the passage of a shallow depression over the Lake Region, a high pressure area, attended by temperatures below freezing, was advancing eastward over the Dakotas on the morning of the 5th, and frost warnings were issued for Wisconsin and portions of Nebraska and Kansas. However, no frost was reported on the morning of the 6th, except on the cranberry marshes of Wisconsin, where minimum temperatures ranged from 15° to 20°.

On the 9th an area of high pressure of great magnitude, with highest pressure 30.7 inches at Miles City, covered the western half of the country, with low pressure over the northeastern States. Warnings of a severe freeze were sent to the cranberry marshes and warnings of a heavy frost to practically all the eastern and southern portions of the district. Heavy to killing frost was almost general on the morning of the 10th, except in portions of Missouri and Kansas, and minimum temperatures of 6° to 11° were registered on the Wisconsin cranberry marshes. Warnings were again issued for Illinois on the 10th, and heavy to killing frosts occurred over most of the State the following night.

Frost warnings that were issued on the 13th for Kansas, portions of Nebraska, Iowa, Missouri, and Illinois were not verified, except in northeastern Illinois, on account of the rapid movement of the high-pressure area and the depression following from the northwest.

No further warnings of importance were issued until the 19th, when a disturbance was advancing rapidly northeastward over the Ohio Valley, followed by a strong area of high pressure and abnormally low temperatures from the northern Rocky Mountain region. Warnings of a hard freeze were issued for Kansas, and forecasts of "rain, turning to snow," for the States east and northeast of Kansas. The forecasts and warnings were fully verified. Freezing temperature and snow were reported as far east as central Illinois, where the snowfall was the earliest of record. Killing frosts having now occurred over the entire district, except eastern Missouri, eastern and southern Illinois, and extreme southeastern Wisconsin, warnings of killing frost were issued on the 20th for eastern Missouri and southern Illinois, and freezing temperature for Wisconsin and northeastern Illinois, where cloudiness was expected to continue. The warnings were not fully verified in Illinois. On the 21st warnings of frost were issued for the vicinity of Chicago and Milwaukee, and killing frost occurred the following night. All stations in the district, except Cairo, had reported killing frost by the 22d, where only light to heavy frost had occurred by the end of the month.

Fire-weather warnings were issued for southern Wyoming on the 3d.—*Chas. L. Mitchell, Assistant Forecaster.*

New Orleans, La., forecast district.—Frost warnings were issued on the 5th for northern and western Oklahoma and the northern portion of west Texas, which were expected to occur in connection with the southeastward movement of an area of high pressure over the Plains States. The high-pressure area moved southeastward with diminished intensity, causing a fall in temperature, but frost did not occur. Frost warnings issued on the 9th for Oklahoma and the northern portion of west Texas failed of verification because cloudy weather persisted in the southwestern quadrant of the high-pressure area which moved southeastward over the Plains States.

On account of the rapid southeastward movement of an area of high pressure from the Canadian Northwest, freezing occurred in the Texas Panhandle and northwestern Oklahoma on the 19th without warning.

Warnings issued on the 19th for freezing in Oklahoma, the northern portion of west Texas, the extreme northwest portion of east Texas, and the northwest portion of Arkansas, and frost for the remainder of Texas, except the southeast portion of east Texas, were verified. Warnings issued on the 20th for freezing in the northern and frost in the southern portion of the district were verified except that frost did not occur on the immediate coast.

Frost warnings issued on the 23d for Oklahoma and the northern portion of west Texas failed of verification because of the sluggish movement of an area of low pressure central on that date over the southern Rocky Mountain region.

Frost warnings issued on the 25th for the interior of the district and on the 26th for Arkansas and the interior of Louisiana were justified.

A special forecast was issued for the rice interests in Arkansas on Wednesday, the 11th, as follows:

Showers will probably extend over Arkansas by Friday.

Showers occurred as forecasted.

Special fire-weather forecasts were issued on the 28th as follows:

Oklahoma: Unsettled weather with southerly winds to-night, 15 to 25 miles per hour, shifting to west and north Sunday.

Arkansas: Unsettled weather with southeast to south winds, 15 to 25 miles per hour to-night, shifting to west and northwest Sunday night.

The wind probably exceeded 15 miles per hour.

No storm warnings were displayed on the west Gulf coast except at stations on the Louisiana and the eastern coast of Texas on the 17th and 18th in connection with the tropical hurricane which moved inland in the vicinity of Mobile, Ala., during the forenoon of the 18th. While verifying wind velocities were not recorded at New Orleans, conditions were such as to fully justify the display of the storm and hurricane warnings. Advisory warnings were received from the central office daily from the 13th until the hurricane moved inland, giving the location and probable movement of the disturbance. The advices were telephoned to ship agents, radiographed to ships at sea, and telegraphed to all coast stations. Shipping heeded the warnings generally and when the hurricane had moved inland on the 18th about 20 steamers, some of which had delayed sailing since the 13th, were waiting to be advised that it was safe to proceed to sea. The steamer *Edward L. Hines* of New Orleans was wrecked by the hurricane off the coast of British Honduras on the night of the 14th. We have been unable to ascertain how many of the crew were drowned.

All small craft on the middle Gulf Coast, being warned in time, put into safe harbors, so that loss to shipping on the open Gulf was reduced to a minimum.

Special forecasts were issued for Shreveport, La., on account of the State fair held at that place November 1 to 6, as follows:

October 28: Generally fair weather is indicated for Shreveport for Sunday, Monday, Tuesday, and Wednesday; temperature changes will not be marked.

October 31: Fair weather is indicated for Shreveport Wednesday, Thursday, and Friday. There will not be much change in temperature.

Fair weather prevailed during the periods covered by the above forecasts and temperature changes were slight.—*I. M. Cline, District Forecaster.*

Denver, Colo., forecast district.—Warnings of heavy frost in localities in western Utah were issued on the 3d. Heavy frost occurred in the vicinity of Salt Lake City. By the morning of the 4th an anticyclonic area had spread eastward over the northern Rocky Mountain region and a barometric depression occupied the Denver district. Warnings of heavy frost were issued for Colorado and Utah. They were verified. At 8 a. m. on the 5th the crest of the high area had increased and overlay Wyoming and the Dakotas. At the same time the southwestern depression had moved rapidly southward to northern Mexico and warnings of frost and freezing temperature were accordingly issued for the district, excepting Arizona. These warnings failed of verification owing to the eastward movement of a low-pressure area from the South Pacific, which moved rapidly inland and caused rain and warmer weather over the greater part of the district. On the 7th warnings of frost were issued for parts of Colorado, Arizona, and Utah. Killing frost occurred at Modena, Utah, and the temperature fell 14 degrees in western Colorado, but cloudy skies prevented the formation of frost in large portions of the areas for which frost was predicted. Heavy frost warnings were issued on the 15th for limited areas in Colorado and Utah and in northern and eastern New Mexico. Heavy frosts were reported in south-central Colorado and northern New Mexico only. The morning map of the 18th showed a depression of considerable intensity central over southeast Colorado, with high-pressure to the northwestward over Montana and British Columbia. Freezing temperatures and rain or snow were forecast for northeast Colorado, and at 8 p. m. warnings of snow, possibly heavy in eastern Colorado, were distributed. Warnings of freezing temperature in northwest Colorado and Utah and temperatures 10 degrees below the freezing point in southeast Colorado, were also distributed. The warnings were verified. On the 19th advices of freezing temperature in Colorado and heavy to killing frosts in eastern New Mexico were issued. This warning was fully verified. Killing frosts were reported at Santa Fe and Roswell, New Mexico. On the 22d advices of temperatures below the freezing point, with snow, were issued for northeast Colorado. The warning was justified, freezing temperature and snow being confined to the northeast part of the State. Freezing temperature warnings were also issued for Colorado, northeast New Mexico, northern Arizona and Utah on the 23d and for Utah on the 28th, and were verified.

Special forecasts, covering 60 hours in advance in most cases, were issued for the sugar-beet districts of Colorado beginning on the 12th. Special extended forecasts for the potato districts were also issued daily after the 16th. These special forecasts were generally successful, and proved of much benefit during the harvesting period. The following extract from a letter received from the manager of the Great Western Sugar Co., Greeley, Colo., under date of October 20, 1916, indicates their value to affected interests:

We appreciate very much the telegraphic forecasts we are receiving daily from your office. These forecasts were of a great deal of value to us during the recent storm in handling of harvest conditions. —*Frederick W. Brist, Assistant Forecaster.*

San Francisco, Cal., forecast district.—The unsettled and showery condition which prevailed at the close of September continued with but slight interruption during the first decade of October. During this period rain fell at intervals in all portions of the district, and the warnings issued were satisfactory.

This period of wet weather occurred during the height of the raisin curing season and when a large portion of the bean crop had just been cut and was drying in the fields. Both crops were badly damaged. Although the trays were stacked, the damp weather continued so long, that mold formed and damaged most of the crop. The beans were too green to stack and were therefore dis-

colored and otherwise damaged.—*G. H. Willson, District Forecaster.*

Portland, Oreg., forecast district.—October was a remarkably dry month in this district. It was not until near its close that general rains occurred, and they did not extend into southern Idaho. During the long dry period, low pressure areas were mostly of the Alberta type, with occasionally one of the South Pacific or Colorado type. They passed eastward either too far north, or too far south to influence the weather in this district, which was controlled for the most part by high pressure areas.

Heavy frosts formed on the 4th, 5th, and 6th, and they brought the growing season to a close, except near the coast. These frosts were predicted 24 hours in advance of their occurrence. Frost warnings were also issued on the 17th, 18th, and 24th. The first two were verified, but the one issued on the 24th was a failure, owing to an unexpected fall in pressure which was attended by a rise in temperature.

During the dry spell there were several days with east winds which dried the soil very rapidly. Forest fires were numerous in logged off sections, but they caused very little damage to green timber. The atmosphere for many days was disagreeably smoky, and the soil was too hard to permit of the usual amount of fall plowing and seeding being done.

The first North Pacific storm made its appearance on the morning of the 28th, and warnings for same were ordered at the entrances to the Strait of Juan de Fuca, and the Gulf of Georgia early that morning, and extended to the remaining stations in this district the evening of the same day. The warnings were continued the next morning at the most exposed stations. The storm of the 28th was followed by another North Pacific storm which required warnings the morning of the 30th, and they were sent to all stations in this district. All the storm warnings were fully verified.

During the night of the 28th the schooner yacht *La Viagera* was blown ashore at Shannons Point, which is 3 miles from Anacortes, Wash. This vessel was blown 30 miles from her course before going ashore, but no lives were lost. The schooner *Grays Harbor*, at 12:30 p. m. October 30, lost her tiller (?) during a terrific gale, when she was 6 miles off Grays Harbor bar. She was later picked up by a tug and towed into the harbor at Astoria, Oreg.—*E. A. Beals, District Forecaster.*

FORECAST DISTRICTS OF THE UNITED STATES.

[Weather Bureau, Washington, Oct. 20, 1916.]

Weekly forecast districts.

On resuming its system of weekly forecasts in 1915 the bureau published [1] a sample weekly forecast with an outline map of the districts into which the United States is divided in preparing those forecasts. To-day there is presented a slight revision of the map of districts for the weekly forecasts together with the detailed description of the districts.

North Atlantic States.—Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut, and eastern New York (the portion of the State east of longitude 76°).

Middle Atlantic States.—Eastern Pennsylvania (west of longitude 77° 30′), New Jersey, Delaware, Maryland, District of Columbia, and Virginia.

South Atlantic and East Gulf States.—North Carolina, South Carolina, Florida, Georgia, Alabama, and Mississippi.

West Gulf States.—Louisiana and Texas.

Ohio Valley and Tennessee.—Tennessee, Kentucky, West Virginia, western Pennsylvania (west of longitude 77° 30′), Ohio and Indiana.

Region of Great Lakes.—Western New York (west of longitude 76°), Michigan, and shores of Lake Ontario, Lake Erie, Lake Huron, Lake Michigan, and Lake Superior.

Plains States and Upper and Middle Mississippi Valleys.—Illinois, Wisconsin, Minnesota, Iowa, North Dakota, South Dakota, Nebraska, Missouri, Kansas, Oklahoma, and Arkansas.

Rocky Mountain and Plateau Regions.—Wyoming, Montana, Idaho, Colorado, New Mexico, Nevada, Utah, and Arizona.

Pacific States.—Washington, Oregon, and California.

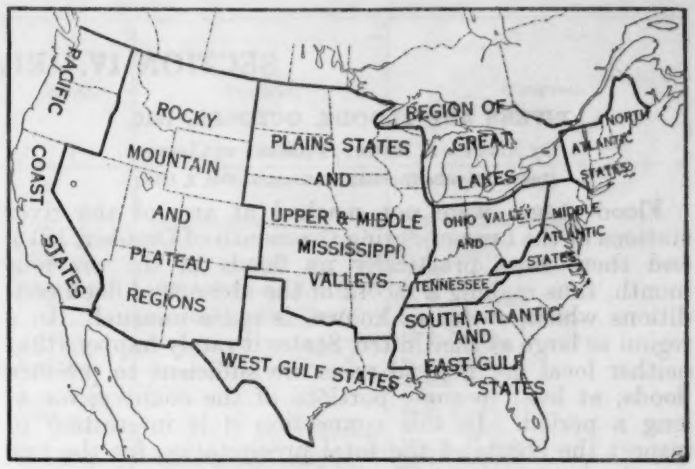

PACIFIC COAST STATES
ROCKY MOUNTAIN AND PLATEAU REGIONS
PLAINS STATES AND UPPER & MIDDLE MISSISSIPPI VALLEYS
REGION OF GREAT LAKES
NORTH ATLANTIC STATES
OHIO VALLEY AND TENNESSEE
MIDDLE ATLANTIC STATES
SOUTH ATLANTIC AND EAST GULF STATES
WEST GULF STATES

FIG. 1.—Districts used for the weekly forecasts.

Daily forecast districts.

In preparing the daily forecasts the following districts are referred to:

North Atlantic States.—Northern New England (Maine, New Hampshire, and Vermont), southern New England (Massachusetts, Rhode Island, and Connecticut), and eastern New York (the portion of the State east of longitude 76°).

Middle Atlantic States.—Eastern Pennsylvania (east of longitude 77° 30′), New Jersey, Delaware, Maryland, District of Columbia, and Virginia.

South Atlantic States.—North Carolina, South Carolina, Georgia, and eastern Florida (as defined in paragraph 432).

East Gulf States.—Western Florida (as defined in paragraph 432), Alabama, and Mississippi.

West Gulf States.—Louisiana and Texas.

Ohio Valley and Tennessee.—Kentucky, West Virginia, western Pennsylvania (west of longitude 77° 30′), Ohio, and Indiana.

Lake Region.—Western New York (west of longitude 76°), Michigan, lower Lakes (Ontario and Erie), and upper Lakes (Huron, Michigan, and Superior).

Upper Mississippi and Missouri Valleys.—Illinois, Wisconsin, Minnesota, Iowa, North Dakota, South Dakota, and Nebraska.

Central Plains States and Middle Mississippi Valley.—Missouri, Kansas, Oklahoma, and Arkansas.

Northern Rocky Mountain States.—Wyoming, Montana, and Idaho.

Southern Rocky Mountain States.—Colorado and New Mexico.

Southern Plateau States.—Nevada, Utah, and Arizona.

Pacific States.—Washington, Oregon, and California.

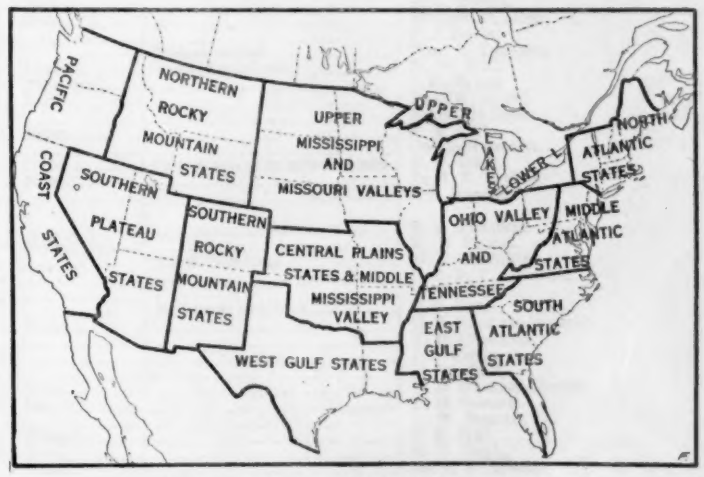


FIG. 2.—Districts used in the daily forecasts.

[1] MONTHLY WEATHER REVIEW, April, 1915, 43:185.

SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, OCTOBER, 1916.

By ALFRED J. HENRY, Professor in Charge.

[Dated: Weather Bureau, Washington, Dec. 2, 1916.]

Flood stages were not reached at any of the river stations of the bureau during the month of October, 1916, and there were practically no floods in the previous month, thus making a record of the absence of flood conditions which, so far as known, is quite unusual. In a region as large as the United States it rarely happens that neither local nor general rains are sufficient to produce floods, at least in some portions of the country, for so long a period. In this connection it is interesting to inspect the charts of the total precipitation for the two months in question. These charts point to the reason for an absence of floods in any part of the country.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

MEAN LAKE LEVELS DURING OCTOBER, 1916.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Nov. 4, 1916.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during October, 1916:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	603.72	580.56	571.90	246.06
Above or below—				
Mean stage of September, 1916	−0.16	−0.20	−0.43	−0.63
Mean stage of October, 1915	+0.99	+0.78	−0.07	+0.89
Average stage for October, last 10 years	+1.12	+0.13	−0.20	+0.32
Highest recorded October stage	+0.16	−2.38	−1.80	−1.75
Lowest recorded October stage	+2.14	+0.96	+1.10	+2.39
Average relation of the October level to—				
September level	0.0	−0.2	−0.2	−0.4
November level	+0.2	+0.3	+0.3	+0.2

SECTION V.—SEISMOLOGY.

SEISMOLOGICAL REPORTS FOR OCTOBER, 1916.

By W. J. HUMPHREYS, Professor in Charge.

[Dated: Weather Bureau, Washington, D. C., Dec. 1, 1916.]

TABLE 1.—*Non-instrumental earthquake reports, October, 1916.*

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		ALABAMA.								
1916.	*H. m.*		° ′	° ′			*M. s.*			
Oct. 18	22 04	Anniston	33 39	85 50	5	2	0 4	None	Furniture moved	U. S. Weather Bureau.
	22 04	Ashville	33 50	86 14	5	2			Many people alarmed	B. B. Cather.
	22 04	Athens	34 50	86 59	5	1	3	None		R. M. Cowls.
	22 04	Auburn	32 34	85 28	3	3	9	....do		James T. Anderson.
	22 04	Benton	32 19	86 47	3-4	1	30	Rumbling	Dishes rattled	S. T. Pruitt.
	22 04	Bessemer	33 25	86 58	4-5		4	....do		D. W. Houston.
	22 04	Birmingham	33 32	86 50	5	3	14	....do	Buildings trembled	U. S. Weather Bureau.
	22 04	Bridgeport	34 57	85 41	2	1	4	....do		R. L. Moore.
	22 04	Calera	33 06	86 45	4	1				D. W. Loyd.
	22 04	Camden	32 00	87 16				Rumbling		W. B. Jones.
	22 04	Camp Hill	32 46	85 37	4					Lyman Ward.
	22 04	Clanton	32 49	85 39	5	1	20	Rumbling		J. B. Downs.
	22 04	Cordova	33 44	87 08	2	3		None		Scott Maxwell.
	22 04	Dadeville	32 48	85 44	2	2	30			W. B. Fulton.
	22 04	Decatur	34 36	87 00	5	2	6			Mrs. A. H. Iron.
	22 04	Easonville	33 32	86 16	7	1	10	Rumbling	Tops of chimneys fell	W. N. Maddox.
	22 04	Eufala	31 52	85 06	3	1		None	Shook some buildings	Dr. J. B. Whitlock.
	22 04	Florence	34 48	87 40	4	1		....do		O'Ella O. Coburn.
	22 04	Fort Deposit	31 59	86 36	2-3	1				J. F. Hattemer.
	22 04	Gadsden	33 59	86 00	3-4	1			Buildings shaken	D. P. Goodhue.
	22 04	Geneva	31 02	85 50	2	1				Postmaster.
	22 04	Goodwater	33 04	86 03	5	1		Rumbling		Miss Daisy Buice.
	22 04	Guntersville	34 22	86 18	5	1	8	....do	Many frightened	L. S. Long.
	22 04	Hamilton	34 07	87 58	5	1		None		H. D. Sargent.
	22 04	Lincoln	33 36	86 03	4	2		....do		R. W. Tuck.
	22 04	Madison	34 41	86 43						J. H. Ganders.
	22 04	Maple Grove	34 09	85 49	5	1		Rumbling		Mrs. A. L. Aubrey.
	22 04	Mentone	34 32	85 33				....do		E. Mason.
	22 04	Milstead	32 27	85 51	4	2				W. U. Wall.
	22 04	Montgomery	32 23	86 18	4	1	3	None	A few persons nauseated	U. S. Weather Bureau.
	22 04	Moulton	34 30	87 18	3-4	2	10	Rumbling		O. L. Judy.
	22 04	Oneonta	33 55	86 29	4-5	2	9		Furniture moved	A. J. Ketchum.
	22 04	Opelika	32 38	85 21						A. H. Read.
	22 04	Ozark	31 28	85 37	2	1	2			Nettie Scott.
	22 04	St. Bernard	34 11	86 48	4				Buildings shaken	Rev. Wm. Geis.
	22 04	Scottsboro	34 40	86 02	4-5	3		Rumbling		Eva Caldwell.
	22 04	Selma	32 05	87 01	3-4	1				C. F. Bristin.
	22 04	Talladega	33 26	86 05	5	3	30	Rumbling	Some plaster fell	J. W. Vandiver.
	22 04	Valley Head	34 32	85 34	2-3					M. T. Floyd.
	22 04	Vernon	33 46	88 06				None	Windows rattled	Mrs. V. Livingston.
	22 04	Wedowee	33 18	85 29	5	1	30	Rumbling	Doors and furniture moved	R. L. Adcock.
19	4 54	Birmingham	33 32	86 50						U. S. Weather Bureau.
	4 54	Easonville	33 32	86 16						W. N. Maddox.
		CALIFORNIA.								
9	4 50	Round Valley	37 24	118 37	3	3	5	Rumbling		Glen H. Crow.
19	11 30	Cahuilla	33 32	116 43	2	1	5	Rumbling		Dr. Wm. L. Shawk.
23	2 44	Bakersfield	35 22	119 00	5	4	6	Rattling		Santa Fe Railway.
	2 44	Bakersfield	35 22	119 00	4	2	4	None		Frank W. Warthout.
	2 44	Claremont	34 06	117 42		1	10			Prof. F. P. Brackett.
	2 44	Edison	35 21	118 53	3	3	20	None	Dishes rattled	L. R. Talbott.
	2 44	Fairmont	34 45	118 25	4	1		Rumbling		W. F. Lowe.
	2 44	Fresno	36 43	119 49	3	1	5	None		U. S. Weather Bureau.
	2 44	Gray Mountain	34 38	116 15	3	3	15	None		B. J. Cloes.
	2 44	Los Angeles	34 03	118 15	4	1	5	None		U. S. Weather Bureau.
	2 44	Maricopa	35 05	119 08	4	2	9	None		F. B. Tough.
	2 44	Mount Wilson	34 13	118 03	2	2	4	None		Wendell P. Hoge.
	2 44	Newhall	34 22	118 30	5	2	6			P. J. Coyle.
	2 44	Nordhoff	34 35	119 14	5	3	6		Dishes rattled	Wm. H. Duncan.
	2 44	Pasadena	34 06	118 11	5	2	30	None	Rattled windows	H. W. Hall.
	2 44	Ozena	34 53	119 16	5	2	40	Rumbling		J. D. Reyes.
	2 44	Redlands	34 04	117 12	3	1		None		Paul W. Moore.
	2 44	Riverside	33 58	117 21	3	2				Riverside Press.
	2 44	Santa Monica	34 00	118 30	5	1	10	None		F. E. Hill.
	2 44	Surrey	35 23	118 32	3	3				George Swanson.
	2 44	Taft	35 07	119 26	5-6	1	13	None	Caused waves on adjacent lake	R. D. Bush.
	2 44	Venice	34 00	118 30	3	1		None		Dr. J. T. Brown.
	2 44	Ventura	34 16	119 17	5	3				J. C. Hansen.
23	2 55	Avalon	33 27	118 22		1				T. S. Manning.
	2 55	Beaumont	33 55	117 00	4-5	2	10	None		K. R. Smoot.
	2 55	Bakersfield	35 22	119 00	4				Shook buildings	W. B. de Billier.
	2 55	Claremont	34 06	117 42		1	10			Prof. F. P. Brackett.
	2 55	Fairmont	34 45	118 25		2				W. F. Lowe.
	2 55	Gray Mountain	34 38	116 15	4	1			Buildings trembled	B. J. Cloes.
	2 55	Los Angeles	34 03	118 15	4	1	5	None		U. S. Weather Bureau.
	2 55	Maricopa	35 05	119 08						V. E. Conkling.
	2 55	Newhall	34 22	118 30	5	2	55			P. J. Coyle.
	2 55	Pasadena	34 06	118 11		1				H. W. Hall.
	2 55	San Luis Obispo	35 18	120 39	2	2	4	None		U. S. Weather Bureau.
	2 55	San Pedro	33 44	118 16	5	2	35	Faint		E. D. Seward.
	2 55	Santa Barbara	34 23	119 40		2				G. W. Russell.
	2 55	Santa Monica	34 00	118 30	4	1	4	None		F. E. Hill.
	2 55	Taft	35 07	119 26	5	2	10	None		R. D. Bush.
	2 55	Venice	34 00	118 30	3	1		None		Dr. J. T. Brown.

TABLE 1.—*Non-instrumental earthquake reports, October, 1916*—Continued.

Day.	Approximate time, Greenwich Civil.	Station.	Approximate latitude.	Approximate longitude.	Intensity Rossi-Forel.	Number of shocks.	Duration.	Sounds.	Remarks.	Observer.
		CALIFORNIA—con.								
1916.	*H. m.*		° ′	° ′			*M. s.*			
Oct. 23	5 20	Brawley	32 59	115 40	4	1		Rumbling		M. D. Witter.
24	13 03	King City	36 14	121 06	5			None		F. J. Merritt.
	13 03	Lonoak	36 20	120 55	3	1		None		M. L. Griffin.
	13 03	San Luis Obispo	35 18	120 39	2	2	6	None		U. S. Weather Bureau.
		COLORADO.								
12	5 40	Frances	40 03	105 32	3–4	1	5	None	Awakened some people	C. W. Barry.
	5 40	Grandlake	40 15	105 50	4	1		Rumbling		Belle Kauffman.
		GEORGIA.								
18	22 04	Atlanta	33 45	84 23	5	2	5	None	Shook buildings	U. S. Weather Bureau.
	22 04	Augusta	33 28	81 54	2	1		None	Windows rattled	Mrs. E. D. Emigh.
	22 04	Blairsville	34 54	83 58	2	2	10	None		C. J. Wellborn.
	22 04	Blue Ridge	34 52	84 21		1			Some objects upset	A. B. Mosly.
	22 04	Canton	34 14	84 29		1	30			Ada Mills.
	22 04	Clayton	34 54	83 23	3	1	30	None		B. L. Bingham.
	22 04	Cleveland	34 36	83 45	5	2		Rumbling		Tressia Carroll.
	22 04	Columbus	32 28	85 00	3	2	30			A. J. Land.
	22 04	Concord	33 05	84 26	4–5	1	10	Rumbling		C. T. Smith.
	22 04	Covington	33 36	83 48				Rumbling		Mrs. Sarah Cruse.
	22 04	Dahlonega	34 32	83 59	2	3		None		Prof. B. P. Gaillard.
	22 04	Dalton	34 46	84 58	3	2	10	None	Windows rattled	B. L. Heartsill.
	22 04	Duluth	34 00	84 08	5	1	25	None		W. O. Medlock.
	22 04	Forsyth	33 02	83 55	3–4	2	15		Buildings trembled	A. M. Zellner.
	22 04	Gainesville	34 17	83 46	5		20	None		W. C. Walker.
	22 04	Griffin	33 16	84 18	2	1	15	Faint		J. M. Mathews.
	22 04	La Fayette	34 42	85 18		1	30	Rumbling		A. S. Sharp.
	22 04	La Grange	33 01	85 01	5	1	10	None		W. L. Ferner.
	22 04	Hiawassee	34 56	83 44	3–4	1	15	None		G. C. Benson.
	22 04	Macon	32 50	83 38	3–4	2			Windows rattled	U. S. Weather Bureau.
	22 04	Madison	33 32	83 28	4–5	2	5	Faint	Pictures swayed	J. W. Owen.
	22 04	Marietta	33 56	84 32		2				A. N. Mayes.
	22 04	Marshallville	32 27	83 55	3	1				E. C. Bryan.
	22 04	Monticello	33 16	83 38	3	2		Rumbling		Miss Maud Penn.
	22 04	Rome	34 15	85 10	3	1				W. M. Towers.
	22 04	Sandersville	32 56	82 48	3				Dishes rattled	Dr. D. Stone.
	22 04	Summerville	34 28	85 20	2	1				J. V. Wheeler, jr.
	22 04	Tallapoosa	33 45	85 18	4	1	10			C. C. Sigman.
	22 04	Thomson	33 27	82 28	3	1	5	None		J. L. West.
	22 04	Thunder	32 56	84 30		1	55	None		E. T. Riggins.
	22 04	Warrenton	33 21	82 37		1				J. C. Evans.
		INDIANA.								
18	22 04	Evansville	37 58	87 33	3	1	4	None		U. S. Weather Bureau.
		KENTUCKY.								
18	22 04	Beaver Dam	37 23	86 53	2	1				W. T. Austin.
	22 04	Calhoun	37 34	87 16		1			Buildings shook slightly	W. A. Taylor.
	22 04	Louisville	38 15	85 45	3	2		None	Windows rattled	U. S. Weather Bureau.
	22 04	Taylorsville	38 02	85 21					Windows rattled	E. D. Bourne.
19	8 00	Mayfield	36 45	88 38		1	50			J. N. Davis.
		MISSISSIPPI.								
18	22 04	Aberdeen	33 50	88 26	2	1		Faint	Slight rattling of dishes	J. E. Spratt.
	22 04	Booneville	34 42	88 28	3	1	2	None	Windows rattled	Dr. D. T. Price.
	22 04	Corinth	34 56	88 25	2	1	10	None		H. E. Meeks.
	22 04	Fulton	34 17	88 20	2	1	30			A. D. Graham.
	22 04	Porterville	32 42	88 22	2–3	1	2	None	Windows rattled	R. H. Clegg.
	22 04	Toomsuba	32 23	88 22	4	1	5	None	Buildings trembled	R. E. Thompson.
		NEVADA.								
11	5 47	McDermitt	41 58	117 45		1				E. D. Hamel.
23	0 20	Millett	39 01	117 15	2	3	6			Ida Jones.
		NORTH CAROLINA.								
18	22 04	Highlands	35 01	83 15	2–3	1	15	None		B. C. Hawkins.
	22 04	Murphy	35 06	84 00		1				Victoria Mingus.
	22 04	Nantahala	35 17	83 43	3	1	10	Rumbling	Cans fell off shelves	J. Z. Wright
		SOUTH CAROLINA.								
18	22 04	Columbia	34 00	81 03	2	2		None		Prof. Stephen Taber.
	22 04	Liberty	34 47	82 42	3	2	15	None		John T. Bogge.
		TENNESSEE.								
18	22 04	Carthage	36 16	85 56		3	3			J. R. Pickering.
	22 04	Charleston	35 16	84 45	2	1	25	None		J. T. Weeks.
	22 04	Chattanooga	35 04	85 14	4–5	1	50	None		U. S. Weather Bureau.
	22 04	Clinton	36 05	84 07	2	1	5	None		H. C. Slover.
	22 04	Copperhill	35 00	84 23	3	1		None	Shook some buildings	Tennessee Copper Co.
	22 04	Lewisburg	35 27	86 48	4–5	1	15	None	Alarmed some people	R. D. Crutcher.
	22 04	Lynnville	35 24	87 02	3–4	1	4	None	Dishes and windows rattled	J. H. Burrow.
	22 04	McMinnville	35 40	85 48	5	3	3	Rumbling		H. H. Stiles.
	22 04	Murfreesboro	35 53	86 26	3–4			Rumbling		E. F. Wright.
	22 04	Nashville	36 10	86 47	4	1	15		Windows rattled	U. S. Weather Bureau.
	22 04	Sewanee	35 13	85 53	5	1		Faint		University of the South.
	22 04	Sparta	35 56	85 27	3–4	2	50	Rumbling		E. H. Hull.
	22 04	Tullahoma	35 23	86 14	2	1		None		R. T. Moore.
	22 04	Walling	35 48	85 35	2	1	2	Rumbling		J. K. Roberts.
	22 04	Waynesboro	35 18	87 45	3	2	4			H. C. Boyd.

TABLE 2.—*Instrumental seismological reports, October, 1916.*

Time used: Mean Greenwich, midnight to midnight. Nomenclature: International.

[For significance of symbols see this REVIEW, January, 1916, p. 39.]

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
Alaska. *Sitka. Magnetic Observatory.* U. S. Coast and Geodetic Survey. J. W. Green.								
Lat., 57° 03′ 00″ N.; long., 135° 20′ 06″ W. Elevation, 15.2 meters.								
Instruments: Two Bosch-Omori, 10 and 12 kg.								
Instrumental constants:				V	T_0			
				E 10	16.6			
				N 10	15 4			
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 31	.....	eP_N...	15 38 43	3	.....	.....	.....	
		S_E....	15 44 40	4	.....	.....	.....	
		S_N....	15 44 45	6	.....	.....	.....	
		L_E....	15 47 30	20	.....	.....	.....	No long waves discernible on N. S.
		M_E....	15 56 10	20	30	.....	.....	
		F_E....	16 30 00	.....	.....	.....	.....	
Arizona. *Tucson. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. P. Ulrich.								
Lat., 32° 14′ 48″ N.; long., 110° 50′ 06″ W. Elevation, 769.6 meters.								
Instruments: Two Bosch-Omori, 10 and 12 kg.								
Instrumental constants:				V	T_0			
				E 10	13.9			
				N 10	19.1			
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	eL_E...	1 55 00	25	.....	.....	.....	
		eL_N...	1 56 00	20	.....	.....	.....	
		M_N....	2 01 00	16	.....	20	.....	
		F_E....	2 09 30	.....	.....	.....	.....	
		F_N....	2 12 42	.....	.....	.....	.....	
3	.....	eL.....	4 49 04	5	.....	.....	.....	
		M.....	4 50 12	8	100	40	.....	
		F.....	5 03 00	.....	.....	.....	.....	
23	.....	eL.....	2 47 30	3	.....	.....	.....	
		M_E....	2 48 22	8	20	.....	.....	
		C_N....	2 50 00	4	.....	.....	.....	
		F_E....	2 59 00	.....	.....	.....	.....	
California. *Berkeley. University of California.*								
Lat., 37° 52′ 16″ N., long., 122° 15′ 37″ W. Elevation, 85.4 meters.								
(*See* Bulletin of the Seismographic Stations, University of California.)								
California. *Mount Hamilton. Lick Observatory.*								
Lat., 37° 20′ 24″ N.; long., 121° 38′ 34″ W. Elevation, 1,281.7 meters.								
(*See* Bulletin of the Seismographic Stations, University of California.								
California. *Point Loma. Raja Yoga Academy.* F. J. Dick.								
Lat., 32° 43′ 03″ N.; long., 117° 15′ 10″ W. Elevation, 91.4 meters.								
Instrument: Two-component, C. D. West seismoscope.								
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 5	.....	.....	.....	.....	*400	*700	.....	Tremors recorded during 24 hours preceding 15h on dates given.
6	.....	.....	.....	.....	*150	*150	.....	
11	.....	.....	.....	.....	*350	*400	.....	
13	.....	.....	.....	.....	*200	*200	.....	
14	.....	.....	.....	.....	*100	*150	.....	

* Amplitudes on instrument.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
California. *Point Loma. Raja Yoga Academy*—Continued.								
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 15	.....	.....	.....	.....	*100	*100	.....	
19	.....	.....	.....	.....	*50	*100	.....	
22	.....	.....	.....	.....	*100	*50	.....	
22	.....	.....	2 55 00	.....	*150	*500	.....	Very light local shock.
24	.....	.....	.....	.....	*300	*300	.....	Tremors recorded during 24 hours preceding 15h.
26	.....	.....	3 53 00	.....	*200	*250	.....	Very light local shock
27	.....	.....	.....	.....	*200	*300	.....	Tremors recorded during 24 hours preceding 15h on dates given.
28	.....	.....	.....	.....	*250	*250	.....	
29	.....	.....	.....	.....	*450	*350	.....	
30	.....	.....	.....	.....	*200	*200	.....	

* Amplitudes on instrument.

California. *Santa Clara. University of Santa Clara.* J. S. Ricard, S. J.

Lat., 37° 26′ 36″ N.; long., 121° 57′ 63″ W. Elevation, 27.43 meters.

(*See* record of the Seismographic Station, University of Santa Clara.)

Colorado. *Denver. Sacred Heart College.* Earthquake Station. A. W. Forstal, S. J.

Lat., 39° 40′ 36″ N.; long., 104° 56′ 54″ W. Elevation, 1,655 meters.

Instrument: Wiechert 80 kg., astatic, horizontal pendulum.

Instrumental constants .....

1915.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 12	II_d	L.....	5 41 00	.....	.....	.....	.....	Felt and heard by many persons in Boulder Co., 25 mi. N. W. of Denver. Apparently merely local.
		M.....	5 41 20	.....	*12000	*12000	.....	
		F.....	5 41 30	.....	.....	.....	.....	
13	.....	L.....	23 15 00	.....	.....	.....	.....	Small irregular waves.
		F.....	23 27 00	.....	.....	.....	.....	
13	.....	L.....	23 35 00	.....	.....	.....	.....	Small waves recurring; activity visible at intervals during day.
		F.....	23 42 00	.....	.....	.....	.....	
22-23	.....	.....	.....	.....	.....	.....	.....	Irregular waves at intervals during day. More noticeable on E–W.
30	.....	.....	.....	.....	.....	.....	.....	Wavelets visible during day, but record spoiled by heavy machinery in motion.
31	I_u	L.....	16 58 00	.....	.....	.....	.....	Record superimposed on that caused by heavy machinery in motion near-by.
		M.....	17 05 00	20	*6000	*6000	.....	
		F.....	17 52 00	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, October, 1916*—Continued.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
District of Columbia. *Washington. Georgetown University.*								
F. A. Tondorf, S. J.								
Lat., 38° 54′ 25″ N.; long., 77° 04′ 24″ W. Elevation, 42.4 meters. Subsoil: decayed diorite.								
Instruments: Wiechert 200 kg., astatic, horizontal pendulums; 80 kg., vertical.								
Astatic pendulums after Mainka, 130 kg.								
			V	T_0	*s*			
Instrumental constants: E			165	5.4	0			
N			143	5.2	0			
Z			*80*	*5.0*	*0*			
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	eP.....	1 35 39	.....	.....	.....	.....	P possibly sooner.
		S_E.....	1 43 13	.....	.....	.....	.....	Heavy microseisms.
		S_N.....	1 43 24	.....	.....	.....	.....	No distinct maximum.
		eL_E...	1 51 41	.....	.....	.....	.....	
		L_N....	1 55 14	30	.....	.....	.....	
		L_E....	1 55 25	30	.....	.....	.....	
		L_N....	2 02 02	30	.....	.....	.....	
		L_E....	2 03 00	30	.....	.....	.....	
		F.....	2 40 00	.....	.....	.....	.....	
3	.....	S_N.....	5 04 00	.....	.....	.....	.....	P lost in microseisms.
		S_E.....	5 04 03	.....	.....	.....	.....	eL difficult.
		eL_E...	5 07 27	.....	.....	.....	.....	
		eL_N...	5 07 35	.....	.....	.....	.....	
		F.....	5 16 00	.....	.....	.....	.....	
18	.....	eP.....	22 05 26	.....	.....	.....	.....	P very doubtful. Microseisms present.
		S_E.....	22 07 51	.....	.....	.....	.....	
		S_N.....	22 07 52	.....	.....	.....	.....	
		eL.....	22 08 24	.....	.....	.....	.....	
		F.....	22 17 ..	.....	.....	.....	.....	End lost in microseisms.
20	.....	eL_E...	17 55 48	30	.....	.....	.....	Heavy microseisms.
		L_E....	17 58 12	30	.....	.....	.....	N–S hardly shows.
		M_E....	18 02 18	20	1	.....	.....	
		F.....	18 05 00	.....	.....	.....	.....	
31	.....	eP_E...	15 43 02	.....	.....	.....	.....	Microseisms present.
		eP_N...	15 43 04	.....	.....	.....	.....	No distinct maximum.
		iS_E...	15 52 57	.....	.....	.....	.....	
		S_N.....	15 53 00	.....	.....	.....	.....	
		eL_E...	16 09 24	30	.....	.....	.....	
		eL_N...	16 09 24	24	.....	.....	.....	
		F.....	17 32 00	.....	.....	.....	.....	
District of Columbia. *Washington. U. S. Weather Bureau.*								
Lat., 38° 54′ 12″ N.; long., 77° 03′ 03″ W. Elevation, 21 meters.								
Instrument: Marvin (vertical pendulum), undamped. Mechanical registration.								
			V	T_0				
Instrumental constants..			110	6.4				
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	I_u.....	P.....	1 35 39	.....	.....	.....	6,200	
		S.....	1 43 26	.....	.....	.....	.....	
		L.....	1 51 38	40	.....	.....	.....	
		L.....	1 58 00	22	.....	.....	.....	
		L.....	2 01 15	16	.....	.....	.....	
		F.....	3 00 00	.....	.....	.....	.....	
3	I_r.....	P.....	5 00 24	.....	.....	.....	1,750	
		S.....	5 03 24	.....	.....	.....	.....	
		L.....	5 04 18	.....	.....	.....	.....	
		F.....	5 20 00	.....	.....	.....	.....	
11	I_r.....	P.....	11 08 54	.....	.....	.....	3,150	Very faint record.
		S.....	11 13 48	.....	.....	.....	.....	
		L.....	11 23 15	14	.....	.....	.....	
		F.....	11 40 00	.....	.....	.....	.....	
11	.....	S.....	18 30 00	.....	.....	.....	.....	P lost in microseisms.
		L?.....	18 38 45	.....	.....	.....	.....	
		L.....	19 02 30	16	.....	.....	.....	
		F.....	19 25 00	.....	.....	.....	.....	
18	II_r.....	P.....	22 05 52	.....	.....	.....	1,020	Alabama earthquake.
		S.....	22 07 42	.....	.....	.....	.....	
		L.....	22 08 07	.....	.....	.....	.....	
		F.....	22 15 00	.....	.....	.....	.....	
20	I_r.....	P.....	17 23 10	.....	.....	.....	4,660	
		S.....	17 29 34	.....	.....	.....	.....	
		L.....	17 38 00	.....	.....	.....	.....	
		L.....	17 51 20	20	.....	.....	.....	
		F.....	19 10 00	.....	.....	.....	.....	
26	I_r.....	P.....	3 30 50	.....	.....	.....	2,640	
		S.....	3 35 06	.....	.....	.....	.....	
		L.....	3 36 03	.....	.....	.....	.....	
		F.....	3 50 00	.....	.....	.....	.....	

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
District of Columbia. *Washington*—Continued.								
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 31	II_u....	P.....	15 43 03	.....	.....	.....	8,700	Amplitudes small but phases fairly well defined.
		S.....	15 52 58	.....	.....	.....	.....	
		SR1?..	15 58 06	.....	.....	.....	.....	
		SR2?..	16 01 40	.....	.....	.....	.....	
		L.....	16 09 18	28	.....	.....	.....	
		L.....	16 16 20	20	.....	.....	.....	
		L.....	16 22 40	20	.....	.....	.....	
		L.....	16 30 00	16	.....	.....	.....	
		F.....	18 00 00	.....	.....	.....	.....	
Hawaii. *Honolulu. Magnetic Observatory.* U. S. Coast and Geodetic Survey. Frank Neumann.								
Lat., 21° 19′ 12″ N.; long., 158° 03′ 48″ W. Elevation, 15.2 meters.								
Instrument: Milne seismograph of the Seismological Committee of the British Association.								
				T_0				
Instrumental constant..				18.6				
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 1	.....	L.....	2 31 06	22	.....	.....	.....	
		M.....	2 32 00	.....	*400	.....	.....	
		C.....	2 42 12	.....	.....	.....	.....	
		F.....	3 28 00	.....	.....	.....	.....	
3	.....	P.....	1 40 00	.....	.....	.....	.....	
		S.....	1 51 00	.....	.....	.....	.....	
		L.....	2 08 00	20	.....	.....	.....	
		M.....	2 13 48	.....	*2300	.....	.....	
		C.....	2 27 18	.....	.....	.....	.....	
		F.....	4 11 00	.....	.....	.....	.....	
11	.....	eL.....	11 09 00	20	.....	.....	.....	
		M.....	11 14 48	.....	*100	.....	.....	
		F.....	11 19 00	.....	.....	.....	.....	
11	.....	L.....	18 19 30	20	.....	.....	.....	Beginning and end obscured by air tremors.
		M.....	18 24 00	.....	*1300	.....	.....	
		C.....	18 38 36	.....	.....	.....	.....	
20	.....	L.....	17 21 12	21	.....	.....	.....	Time of end doubtful.
		M.....	17 22 00	.....	*2000	.....	.....	
		C.....	17 46 48	.....	.....	.....	.....	
		F.....	18 30 —	.....	.....	.....	.....	
20	.....	eL.....	19 44 18	20	.....	.....	.....	
		M.....	19 48 12	.....	*200	.....	.....	
		F.....	19 57 12	.....	.....	.....	.....	
21	.....	eL.....	20 16 12	.....	.....	.....	.....	Merely a broadening of the line.
		F.....	20 35 00	.....	.....	.....	.....	
21	.....	P.....	22 01 30	.....	.....	.....	.....	
		L.....	22 18 12	20	.....	.....	.....	
		M.....	22 30 30	.....	*100	.....	.....	
		F.....	23 19 00	.....	.....	.....	.....	
22	.....	P.....	7 38 00	.....	.....	.....	.....	
		L.....	7 42 54	21	.....	.....	.....	
		M.....	7 47 30	.....	*100	.....	.....	
		F.....	7 54 48	.....	.....	.....	.....	
23	.....	eL.....	10 41 24	18	.....	.....	.....	
		M.....	10 44 30	.....	*100	.....	.....	
		F.....	10 47 30	.....	.....	.....	.....	
26	.....	eL.....	2 46 36	19	.....	.....	.....	
		M.....	2 51 12	.....	*200	.....	.....	
		F.....	3 02 00	.....	.....	.....	.....	
26	.....	P.....	5 58 00	.....	.....	.....	.....	Phases uncertain.
		L.....	6 02 06	.....	.....	.....	.....	
		M.....	6 11 12	.....	*200	.....	.....	
		C.....	6 14 00	.....	.....	.....	.....	
26	.....	L.....	18 45 06	20	.....	.....	.....	
		M.....	18 52 18	.....	*100	.....	.....	
		C.....	18 55 36	.....	.....	.....	.....	
		F.....	19 33 00	.....	.....	.....	.....	
30	.....	eL.....	2 28 30	19	.....	.....	.....	
		M.....	2 32 00	.....	*100	.....	.....	
		C.....	2 44 00	.....	.....	.....	.....	
30	.....	eL.....	11 35 30	18	.....	.....	.....	
		M.....	11 37 54	.....	*100	.....	.....	
		F.....	11 40 30	.....	.....	.....	.....	
31	.....	P.....	15 39 18	.....	.....	.....	.....	Paper changed at 17h 29m before end of quake.
		S.....	15 46 12	.....	.....	.....	.....	
		eL.....	15 53 36	20	.....	.....	.....	
		M.....	16 00 00	.....	*3900	.....	.....	
		C.....	16 29 30	.....	.....	.....	.....	

* Trace amplitude.

TABLE 2.—*Instrumental seismological reports, October, 1916*—Continued.

Kansas. *Lawrence. University of Kansas.* Department of Physic and Astronomy. F. E. Kester.

Lat., 38° 57′ 30″ N.; long., 95° 14′ 58″ W. Elevation, 301.1 meters.

Instrument: Wiechert.

Instrumental constants.. {E V 177, T_0 3.4, ε 4; N V 205, T_0 3.4, ε 4}

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	P.....	1 36 00	.....	.....	.....	.....	N–S component not free.
		L.....	1 43 58	.....	.....	.....	.....	
		M_E....	1 44 11	.....	3	.....	.....	
		F.....	2 00 00	.....	.....	.....	.....	
18	.....	P.....	22 05 09	.....	.....	.....	.....	
		L?....	22 07 12	.....	.....	.....	.....	
		M_N....	22 07 51	.....	.....	5	.....	
		M_E....	22 07 55	.....	6	.....	.....	
		F.....	22 30 00	.....	.....	.....	.....	

Maryland. *Cheltenham. Magnetic Observatory.* U. S. Coast and Geodetic Survey. George Hartnell.

Lat., 38° 44′ 00″ N.; long., 76° 50′ 30″ W. Elevation, 71.6 meters.

Instruments: Two Bosch-Omori, 10 and 12 kg.

Instrumental constants.. {E V 10, T_0 32; N V 10, T_0 27}

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	eP_N....	1 36 04	3	.....	.....	.....	
		S_N....	1 43 24	16	.....	.....	.....	
		S_E....	1 43 28	8	.....	.....	.....	
		L_N....	1 52 24	24	.....	.....	.....	
		M_E....	1 58 40	20	20	.....	.....	
		M_N....	2 02 40	20	.....	20	.....	
		F.....	2 20 00	.....	.....	.....	.....	
18	.....	e_E....	22 08 10	.....	.....	.....	.....	Reported as being felt in southern States.
		e_N....	22 08 15	.....	.....	.....	.....	
		M_E....	22 08 36	3	10	.....	.....	
		M_N....	22 08 56	3	.....	10	.....	
		F.....	22 10 00	.....	.....	.....	.....	
31	.....	P_E....	15 53 05	.....	.....	.....	.....	
		P_N....	15 53 11	.....	.....	.....	.....	
		S_N....	16 01 17	.....	.....	.....	.....	
		M_E....	16 23 00	19	30	.....	.....	
		M_N....	16 33 00	17	.....	20	.....	
		F_E....	16 35 00	.....	.....	.....	.....	
		F_N....	16 45 00	.....	.....	.....	.....	

Massachusetts. *Cambridge. Harvard University Seismographic Station,* J. B. Woodworth.

Lat., 42° 22′ 36″ N.; long., 71° 06′ 59″ W. Elevation, 5.4 meters. Foundation, Glacial sand over clay.

Instruments: Two Bosch-Omori 100 kg. horizontal pendulums (mechanical registration)

Instrumental constants.. {E V 80, T_0 23, ε 0; N V 50, T_0 25, ε 4:1}

(Report for October, 1916, not received.)

Missouri. *Saint Louis. St. Louis University.* Geophysical Observatory. J. B. Goesse, S. J.

Lat., 38° 38′ 15″ N.; long., 90° 13′ 58″ W. Elevation, 160.4 meters. Foundation: 12 feet of tough clay over limestone of Mississippi system, about 300 feet thick.

Instruments: Wiechert 80 kg, astatic, horizontal pendulum.

Instrumental constants.. V 80, T_0 7, ε 5:1

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 31	.....	P_E....	15 42 30	.....	.....	.....	.....	N–S component blurred by local disturbances.
		S_E?...	15 48 40	.....	.....	.....	.....	
		M_E....	15 52 00	12	31	.....	.....	
		F.....	16 34 00	.....	.....	.....	.....	

New York. *Buffalo. Canisius College.* John A. Curtin, S. J.

Lat., 42° 53′ 02″ N.; long., 78° 52′ 40″ W. Elevation, 190.5 meters.

Instrument: Wiechert 80 kg. horizontal.

Instrumental constants.. V 80, T_0 7, ε 5:1

(Report for October, 1916, not received.)

New York. *Fordham. Fordham University.* W. C. Repetti, S. J.

Lat., 40° 51′ 47″ N.; long., 73° 53′ 08″ W. Elevation, 23.9 meters.

Instrument: Weichert, 80 kg.

Instrumental constants.. {E V 72, T_0 7.1, ε 1.5:1; N V 72, T_0 6.8, ε 3.8:1}

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	eP_N....	1 30 24	.....	.....	.....	.....	
		eP_E....	1 30 25	.....	.....	.....	.....	
		S_N....	1 39 12	.....	.....	.....	.....	
		iS_E....	1 39 17	.....	.....	.....	.....	
		L_E?...	1 44 52	.....	.....	.....	.....	
		L_N....	1 46 59	.....	.....	.....	.....	
		M_N....	1 55 17	23	.....	7	.....	
		F_N....	2 25 52	.....	.....	.....	.....	
3	.....	L_N....	5 00 33	.....	.....	.....	.....	
		M_N....	5 03 17	7	.....	4	.....	
		F_N....	5 07 00	.....	.....	.....	.....	
18	.....	e_N....	22 04 12	.....	.....	.....	.....	
		e_E....	22 04 24	.....	.....	.....	.....	
		F_N....	22 11 00	.....	.....	.....	.....	
		F_E....	22 12 00	.....	.....	.....	.....	
20	.....	eL_N...	17 45 44	21	.....	.....	.....	
		F.....	18 11 00	.....	.....	.....	.....	
26	.....	i.....	3 30 30	.....	.....	.....	.....	
		F_E....	3 33 50	.....	.....	.....	.....	
		F_N....	3 34 50	.....	.....	.....	.....	

New York. *Ithaca. Cornell University.* Heinrich Ries.

Lat., 42° 26′ 58″ N.; long., 76° 29′ 09″ W. Elevation, 242.6 meters.

Instruments: Two Bosch-Omori, 25 kgm., horizontal pendulums (mechanical registration).

Instrumental constants.. {E V 13, T_0 22, ε 4:1; N V 14, T_0 25, ε 4:1}

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	eP_N....	1 36 38	5	.....	.....	.....	
		eP_E....	1 36 50	4	.....	.....	.....	
		S_N....	1 44 30	4–8	.....	.....	.....	
		S_E....	1 44 34	4–7	.....	.....	.....	
		L_E....	1 51 38	24	.....	.....	.....	
		L_N....	1 57 08	30	.....	.....	.....	
		F_E....	2 13 00	.....	.....	.....	.....	
		F_N....	2 21 00	.....	.....	.....	.....	
3	.....	e_N....	5 04 49	3–7	.....	.....	.....	
		e_E....	5 07 30	9	.....	.....	.....	
		F_N....	5 12 00	.....	.....	.....	.....	
31	.....	eP_E....	15 53 14	5	.....	.....	.....	
		e_N....	15 03 07	17	.....	.....	.....	
		eL_N...	16 10 10	28	.....	.....	.....	
		eL_E...	16 11 50	20	.....	.....	.....	
		F_N....	16 53 00	.....	.....	.....	.....	

TABLE 2.—*Instrumental seismological reports, October, 1916*—Continued.

Panama Canal Zone. *Balboa Heights.* Isthmian Canal Commission.

Lat., 8° 57′ 39″ N.; long., 79° 33′ 29″ W. Elevation, 27.6 meters.

Instruments: Two Bosch-Omori, 100 kg.

Instrumental constants.. V 10, T_0 20

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	P.....	1 31 55	.....	.....	.....	1,770	Direction N?
		S_N....	1 35 25	.....	.....	.....	.....	
		L_N....	1 37 00	.....	.....	.....	.....	
		L_E....	1 37 05	.....	.....	.....	.....	
		M_N....	1 38 20	.....	.....	150	.....	
		M_E....	1 39 35	.....	50	.....	.....	
		F_E....	2 20 00	.....	.....	.....	.....	
		F_N....	2 33 00	.....	.....	.....	.....	
15	.....	P.....	1 25 10	.....	.....	.....	260	Direction?
		L_E....	1 25 39	.....	.....	.....	.....	
		L_N....	1 25 40	.....	.....	.....	.....	
		M_N....	1 25 44	.....	.....	50	.....	
		M_E....	1 25 47	.....	50	.....	.....	
		F_E....	1 28 40	.....	.....	.....	.....	
		F_N....	1 29 20	.....	.....	.....	.....	

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 08′ 48″ N.; long., 65° 26′ 54″ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.. E: V 10, T_0 21.4; N: V 10, T_0 21.1

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	eP.....	1 33 09	4	.....	.....	.....	Phases uncertain.
		M_E....	1 48 30	24	20	.....	.....	
		M_N....	1 50 40	16	.....	20	.....	
		F_N....	2 17 00	.....	.....	.....	.....	
		F_E....	2 28 00	.....	.....	.....	.....	

Vermont. *Northfield. U. S. Weather Bureau.* Wm. A. Shaw.

Lat., 44° 10′ N.; long., 72° 41′ W. Elevation, 256 meters.

Instruments: Two Bosch-Omori, mechanical registration.

Instrumental constants.. E: V 10, T_0 15; N: V 10, T_0 16

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	I_E.....	P.....	1 36 12	.....	.....	.....	6,990	Record feeble; does not show on E–W.
		S.....	1 44 40	.....	.....	.....	.....	
		L.....	1 59 30	20	.....	.....	.....	
		F.....	2 15 00	.....	.....	.....	.....	
3	.....	e_N.....	5 05 00	.....	.....	.....	.....	Phases indistinguishable. Does not show on E–W.
		F.....	5 20 00	.....	.....	.....	.....	
11	.....	e.....	11 08 22	.....	.....	.....	.....	
		F.....	11 15 00	.....	.....	.....	.....	
11	.....	e.....	18 30 10	.....	.....	.....	.....	
		F.....	18 40 00	.....	.....	.....	.....	
31	I_E.....	P.....	15 42 39	.....	.....	.....	8,820	
		S.....	15 52 40	.....	.....	.....	.....	
		L_E....	16 06 00	.....	.....	.....	.....	
		L.....	16 13 00	20	.....	.....	.....	
		L.....	16 19 00	18	.....	.....	.....	
		F.....	17 00 00	.....	.....	.....	.....	

Canada. *Ottawa. Dominion Astronomical Observatory.* Earthquake Station. Otto Klotz.

Lat., 45° 23′ 38″ N.; long. 75° 42′ 57″ W. Elevation, 83 meters.

Instruments: Two Bosch photographic horizontal pendulums, one Spindler & Hoyer 80 kg. vertical seismograph.

Instrumental constants: V 120, T_0 26.

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
1916.			*H. m. s.*	*Sec.*	μ	μ	*Km.*	
Oct. 3	.....	*O*.....	*1 29 19*	.....	.....	.....	6,630	
		eP_N...	1 36 26	.....	.....	.....	.....	
		iP_N...	1 36 32	.....	.....	.....	.....	
		eS_E...	1 44 36	.....	.....	.....	.....	
		iS_N...	1 44 42	.....	.....	.....	.....	
		eL.....	1 54 36	36	.....	.....	.....	
		L.....	1 59 00	32	.....	.....	.....	
		L.....	2 01 00	28–26	.....	.....	.....	
		L.....	2 05 00	18–16	.....	.....	.....	
		L.....	2 12 00	17	.....	.....	.....	
		L.....	2 23 00	15–14	.....	.....	.....	
		L.....	2 32 00	14	.....	.....	.....	
		F.....	3 00 00	.....	.....	.....	.....	
3	.....	*O*?....	*4 52 42*	.....	.....	.....	4,000?	
		e_E?....	4 59 00	.....	.....	.....	.....	
		e_N.....	5 04 17	.....	.....	.....	.....	
		i_N.....	5 04 46	.....	.....	.....	.....	
		eL_E?..	5 08 00	10	.....	.....	.....	
		F.....	5 23 00	.....	.....	.....	.....	
11	.....	iS?.....	11 11 14	.....	.....	.....	6,000?	
		iSR1?.	11 15 21	.....	.....	.....	.....	
		eL?...	11 22 00	.....	.....	.....	.....	
		L.....	11 25 24	16	.....	.....	.....	
		F.....	11 45 00	.....	.....	.....	.....	
11	.....	*O*?....	*18 15 30*	.....	.....	.....	5,500?	
		e.....	18 31 23	.....	.....	.....	.....	
		iS?....	18 31 38	.....	.....	.....	.....	
		L.....	18 39 30	20	.....	.....	.....	
		L.....	18 44 00	27	.....	.....	.....	
		L.....	19 07 00	17	.....	.....	.....	
		F.....	.....	.....	.....	.....	.....	
13	.....	L.....	1 34 00	20	.....	.....	.....	Only a trace.
20	.....	e_E.....	17 16 17	.....	.....	.....	9,700?	
		e_N.....	17 16 22	.....	.....	.....	.....	
		L_E....	17 46 30	20	.....	.....	.....	
		L_N....	17 51 24	40	.....	.....	.....	
		LR1?.	19 20 48	10	.....	.....	.....	
		F.....	19 40 00	.....	.....	.....	.....	
21	.....	L_N....	20 35 00 20 45 00	30–20	.....	.....	.....	
		F.....	21 00 00	.....	.....	.....	.....	
21	.....	eL.....	22 35 00	24?	.....	.....	.....	
		L.....	22 45 00	20	.....	.....	.....	
		L.....	22 56 00	18	.....	.....	.....	
		F.....	23 10 00	.....	.....	.....	.....	
31	.....	eL.....	16 09 12	24	.....	.....	.....	First phases lost in changing sheets.
		L.....	16 17 00	24	.....	.....	.....	
		L.....	16 24 00 17 05 00	15	.....	.....	.....	
		F.....	17 30 00	.....	.....	.....	.....	

O=time at origin.

TABLE 2.—*Instrumental seismological reports, October, 1916*—Continued.

Canada. *Toronto. Dominion Meteorological Service.*

Lat., 43° 40′ 01″ N.; long., 79° 23′ 54″ W. Elevation, 113.7 meters. Subsoil: Sand and clay.

Instrument: Milne horizontal pendulum, North. In the meridian.

Instrumental constant.. T_0 18. Pillar deviation: 1 mm. swing of boom = 0.50″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1916. Oct. 1	.....	L.....	2 10 30	.....	*100	.....	.....	Preceded and followed by air currents.
		F.....	2 14 42	.....	.....	.....	.....	
3	.....	iP.....	1 36 48	.....	.....	.....	6,785	Possibly off the coast of Peru.
		iS.....	1 45 06	.....	.....	.....	.....	
		L.....	1 52 30	.....	.....	.....	.....	
		L.....	1 56 42	.....	.....	.....	.....	
		L.....	2 00 18	.....	.....	.....	.....	
		M.....	2 03 18	.....	*1,500	.....	.....	
		L.....	2 09 36	.....	.....	.....	.....	
		L.....	2 14 36	.....	.....	.....	.....	
		L.....	2 19 36	.....	.....	.....	.....	
		L.....	2 42 18	.....	.....	.....	.....	F in air currents.
3	.....	iL?....	5 01 18	.....	.....	.....	.....	Air currents going on.
3	.....	L.....	14 01 48	.....	*200	.....	.....	Doubtful as to being seismic. F in air currents.
6	.....	e?.....	16 28 48	.....	*100	.....	.....	Doubtful as to being seismic. F in air currents.
11	.....	L.....	10 48 24	.....	.....	.....	.....	Doubtful as to being seismic.
		L.....	11 04 54	.....	*100	.....	.....	
		L.....	11 19 18	.....	.....	.....	.....	F in air currents.
11	.....	e?.....	18 24 36	.....	.....	.....	.....	
		e.....	18 28 00	.....	.....	.....	.....	
		L.....	18 40 00	.....	.....	.....	.....	
		eL.....	19 04 00	.....	.....	.....	.....	
		M.....	19 05 48	.....	*300	.....	.....	F in air currents.
13	.....	L.....	1 14 18	.....	.....	.....	.....	F in air currents.
20	.....	L?.....	17 33 18	.....	.....	.....	.....	
		M.....	17 34 48	.....	*200	.....	.....	F lost in air currents.
21	.....	e.....	20 42 36	.....	*50	.....	.....	Minute thickening.
		F.....	20 45 06	.....	.....	.....	.....	
21	.....	e?.....	22 23 06	.....	.....	.....	.....	Air currents going on, phases rather doubtful.
		L.....	22 40 06	.....	.....	.....	.....	
		eL.....	22 53 24	.....	.....	.....	.....	
		M.....	22 54 24	.....	*300	.....	.....	F lost in air currents.
22	.....	eL.....	8 29 00	.....	*100	.....	.....	Gradual thickening.
		F.....	8 36 30	.....	.....	.....	.....	
31	.....	iP.....	15 52 18	.....	.....	.....	7,600	Phases well defined. P and S strongly marked at commencement.
		eS.....	16 01 18	.....	.....	.....	.....	
		L?.....	16 08 00	.....	.....	.....	.....	
		iL.....	16 11 00	.....	.....	.....	.....	
		L.....	16 18 36	.....	.....	.....	.....	
		eL.....	16 19 30	.....	.....	.....	.....	
		M.....	16 24 24	.....	*2,800	.....	.....	
		L.....	17 03 24	.....	.....	.....	.....	
		F.....	18 54 12	.....	.....	.....	.....	

* Trace amplitude.

Canada. *Victoria, B. C. Dominion Meteorological Service.*

Lat., 48° 24′ N.; long., 123° 19′ W. Elevation, 67.7 meters. Subsoil: Rock.

Instrument: Wiechert, vertical; Milne horizontal pendulum, North. In the meridian.

Instrumental constant.. T_0 18. Pillar deviation: 1 mm. swing of boom = 0.54″.

Date.	Character.	Phase.	Time.	Period T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.
			H. m. s.	*Sec.*	μ	μ	*Km.*	
1916. Oct. 1	.....	P or L?	2 54 32	.....	.....	.....	.....	
		M.....	2 56 31	.....	*50	.....	.....	
		F.....	2 58 00	.....	.....	.....	.....	
3	.....	P.....	1 38 31	.....	.....	.....	9,400	
		S.....	1 49 01	.....	.....	.....	.....	
		L.....	1 58 31	.....	.....	.....	.....	
		M.....	2 13 31	.....	*2,500	.....	.....	
		F?.....	4 22 48	.....	.....	.....	.....	F may be reflected waves.
3	.....	eL.....	4 56 30	.....	*300	.....	.....	
		F.....	4 59 31	.....	.....	.....	.....	
3	.....	P.....	13 40 41	.....	.....	.....	.....	
		L.....	13 43 50	.....	.....	.....	.....	
		M.....	13 44 51	.....	*200	.....	.....	
		F.....	13 48 22	.....	.....	.....	.....	
6	.....	P or L.	16 24 58	.....	.....	.....	.....	
		M.....	16 27 57	.....	*200	.....	.....	
		F.....	16 30 26	.....	.....	.....	.....	
11	.....	P?.....	11 31 34	.....	.....	.....	.....	
		M.....	11 32 34	.....	*100	.....	.....	
		F.....	11 38 01	.....	.....	.....	.....	
11	.....	L.....	18 27 36	.....	.....	.....	.....	
		M.....	18 28 08	.....	*500	.....	.....	
		F.....	18 34 03	.....	.....	.....	.....	
11	.....	L.....	18 46 56	.....	.....	.....	.....	Probably another quake, separate from above.
		M.....	18 56 22	.....	*200	.....	.....	
		F.....	19 26 07	.....	.....	.....	.....	
13	.....	P?.....	1 13 08	.....	.....	.....	.....	
		L.....	1 14 48	.....	.....	.....	.....	
		M.....	1 16 17	.....	*200	.....	.....	
		F.....	1 18 16	.....	.....	.....	.....	
19	.....	P or L.	11 57 16	.....	.....	.....	.....	
		M.....	11 58 16	.....	*50	.....	.....	
		F.....	12 00 46	.....	.....	.....	.....	
20	.....	P.....	17 27 20	.....	.....	.....	2,440	
		S.....	17 31 20	.....	.....	.....	.....	
		L.....	17 37 50	.....	.....	.....	.....	
		M.....	17 46 50	.....	*750	.....	.....	
		F.....	18 36 20	.....	.....	.....	.....	
21	.....	P?.....	22 35 37	.....	.....	.....	.....	P, S, and L uncertain
		S?.....	22 37 35	.....	.....	.....	.....	
		L.....	22 40 34	.....	.....	.....	.....	
		M.....	22 44 02	.....	*400	.....	.....	
		F.....	23 08 49	.....	.....	.....	.....	
22	.....	P?.....	8 02 59	.....	.....	.....	.....	
		M.....	8 06 29	.....	*100	.....	.....	
		F.....	8 10 59	.....	.....	.....	.....	
23	.....	P?.....	10 58 03	.....	.....	.....	.....	
		S?.....	11 00 32	.....	.....	.....	.....	
		L.....	11 05 00	.....	.....	.....	.....	
		M.....	11 07 29	.....	*100	.....	.....	
		F.....	11 10 27	.....	.....	.....	.....	
25	.....	P?.....	8 56 34	.....	.....	.....	.....	
		L?.....	8 58 34	.....	.....	.....	.....	
		M.....	9 00 04	.....	*100	.....	.....	
		F.....	9 05 04	.....	.....	.....	.....	
26	.....	L?.....	19 05 11	.....	.....	.....	.....	
30	.....	P?.....	11 33 37	.....	.....	.....	.....	
		M.....	11 35 06	.....	*100	.....	.....	
		F.....	11 39 35	.....	.....	.....	.....	
31	.....	P?.....	15 37 40	.....	.....	.....	.....	
		S.....	15 40 08	.....	.....	.....	.....	
		L.....	15 46 35	.....	.....	.....	.....	
		M.....	15 52 32	.....	1,000	.....	.....	
		F?.....	17 40 08	.....	.....	.....	.....	
		Reflect	18 38 39	.....	.....	.....	.....	

*Trace amplitude.

TABLE 3.—*Late seismological reports.* (*Instrumental.*)

Date.	Character.	Phase.	Time.	Period. T.	Amplitude. A_E	Amplitude. A_N	Distance.	Remarks.

Porto Rico. *Vieques. Magnetic Observatory.* U. S. Coast and Geodetic Survey. F. L. Adams.

Lat., 18° 08′ 48″ N.; long., 65° 26′ 54″ W. Elevation, 19.8 meters.

Instruments: Two Bosch-Omori.

Instrumental constants.

	V	T_0
E	10	21.4
N	10	21.1

			H. m. s.	Sec.	μ	μ	Km.
1916. Sept. 23	.....	P.....	5 48 00	4	.....	.....	.....
		S_E.....	5 52 20	10	.....	.....	.....
		S_N.....	5 52 31	7	.....	.....	.....
		L_E.....	5 54 00	18	.....	.....	.....
		L_N.....	5 54 47	15	.....	.....	.....
		M_E.....	5 57 30	18	30	.....	.....
		M_N.....	5 58 50	14	.....	20	.....
		C.....	6 05 00	13	.....	.....	.....
		F.....	6 18 00	.....	.....	.....	.....

SEISMOLOGICAL DISPATCHES.[1]

Redding, Cal., Oct. 5, 1916.

Lassen Peak was in eruption two hours to-day, spouting steam and smoke from the northern part of the crater. [See above, p. 571.—C. A. jr.] (Assoc. Press.)

Denver, Colo., Oct. 12, 1916.

A fault in the earth's crust which occurred in the mountains near Boulder, last night, was registered on the seismograph of the Sacred Heart College, here. The registration, similar to that of an earthquake, occurred at 10:41 p. m. There were fifteen distinct shocks, lasting 30 seconds. (Assoc. Press.)

Atlanta, Ga., Oct. 18, 1916.

Two distinct earthquake shocks, that in some instances shook frame buildings and knocked chimneys down, were felt throughout Georgia and eastern Alabama and Tennessee shortly after 4 o'clock to-day. From all points damage was reported as negligible except around Birmingham and Montgomery, where it appeared to consist of damage to chimneys. The tremor was not felt at any point east of a suburb of Augusta, Ga., according to press reports to-night, some of which said the first shock was heavier than the second, while others reversed the description. Two distinct shocks were felt in Macon and Columbus, Ga. (Assoc. Press.)

Birmingham, Ala., Oct. 18, 1916.

Birmingham had the severest earthquake in her history this afternoon at 2 minutes past 4 o'clock. There were three sharp and distinct shocks separated by brief intervals. Little property damage was caused other than broken windows and toppled chimneys. (Assoc. Press.)

Louisville, Ky., Oct. 18, 1916.

A slight earthquake shock was felt over a wide area in Louisville at 4:05 o'clock to-day. Police reported that down town tall buildings noticeably were rocked, while in the outlying districts pictures swayed and chinaware rattled. (Assoc. Press.)

Los Angeles, Cal., Oct. 22, 1916.

Two slight earthquake shocks were felt here and in neighboring towns early to-night. Chandeliers and pictures on walls were shaken and crockery was tumbled from shelves. No material damage reported. The first shock was felt at 6:45 p. m., the second 10 minutes later. Each lasted several seconds. Reports from Santa Ana, where the shocks seemed to be felt more perceptibly, said that residents rushed into the streets considerably alarmed. (Assoc. Press.)

Fresno, Cal., Oct. 22, 1916.

According to reports received here two earth shocks that were felt throughout southern California early to-night were severe at Bakersfield and in the oil fields in that district. (Assoc. Press.)

Birmingham, Ala., Oct. 22, 1916.

What was thought to have been a slight earth tremor was felt by persons in various sections of Birmingham to-day. No damage reported. (Assoc. Press.)

Unionville, Nev.

Mr. George Bice, of Unionville, Nev., reports that earthquake shocks were felt in this vicinity at 9:40 and 9:45 p. m. on Oct. 20 and at 8:50 and 11:10 a. m. on Oct. 21, Pacific time. (?clipping?)

The Alabama earthquake of October 18, 1916, detailed reports of which are given in Table 1, above, was so widespread in its effects that it warrants some investigation and discussion. The United States Geological Survey has examined the supposed epicenter and a short article on this disturbance will appear in an early number of the REVIEW.— *W. J. H.*

[1] Reported by the organization indicated and collected by the seismological station of Georgetown University, Washington, D. C.

SECTION VI.—BIBLIOGRAPHY.

RECENT ADDITIONS TO THE WEATHER BUREAU LIBRARY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The following books have been selected from among the titles of books recently received as representing those most likely to be useful to Weather Bureau officials in their meteorological and seismological work and studies:

Abbot, C[harles] G[reeley], & Aldrich, L[oyal] B[laine].
On the use of the pyranometer. Washington. 1916. 9 p. 24½ cm. (Smithsonian miscellaneous collections, v. 66, no. 11.)

Bigourdan, G[uillaume].
Le climat de la France.—Témperature, pression, vents. Paris. 1916. 135 p. 23 cm.

Canada. Meteorological service.
Report for the year ended December 31, 1913. Ottawa. 1916. xv,605 p. 4 pl. 29 cm.

Coímbra. Observatório meteorológico.
Observaçôes, 1915, v. 54. Coímbra. 1916. ix, 165 p. 39 cm.

Colamonico, Carmelo.
La pioggia nella Campania. Firenze. 1915. 180 p. 2 pl. 24 cm. (Memorie geografiche, 1915, n. 27.)

Colombo observatory.
Report of Colombo observatory and the meteorology of Ceylon, 1915. [Colombo. 1916.] 41 p. 8 charts. 33½ cm.

Hall, Maxwell.
Report on the hurricane in Jamaica, August 15th and 16th, 1916. Jamaica. 1916. 10 p. 3 pl. 33½ cm.

Japan. Central meteorological observatory.
Annual report: Meteorological observations in Japan for the year 1915. Tôkyô. 1916. 391 p. map. 30 cm.

Jefferson, Mark.
Teachers' geography. Man and climate. Ypsilanti, Mich. 1916. 2 p.l., 77,[3]p. illus. (incl. maps), diagrs. 27 cm.

Mackay, A. H.
The phenology of Nova Scotia, 1915. (*In* Nova Scotia institute of science. Proc. & trans. Halifax. v. 14, pt. 2, sess. 1915–1916, p. 133–140.)

Navarro Neumann, Emm. Mª. S.
Essais géophysiques. Travail produit par un tremblement de terre. Modena. 1915. 15 p. 24½ cm.

Palmer, George T., Coleman, Laurence V., & Ward, Harry C.
A study of methods for determining air dustiness. p. 1049–1075. 25 cm. (Reprinted from American journal of public health, Boston, v. 6, no. 10.) [Investigation conducted under joint direction of the New York State commission on ventilation, the American museum of natural history, and the American museum of safety, 1915–1916.]

Sutton, J. R.
A note on the temperatures of the air observed at Mochudi. p. 163–167. 25½ cm. (From Transactions, Royal society of South Africa, v. 4, pt. 3, 1915.)

Toronto observatory.
Results of meteorological, magnetical, and seismological observations, 1915. Toronto. 1916. 37, [10] p. 19½ cm.

RECENT PAPERS BEARING ON METEOROLOGY AND SEISMOLOGY.

C. FITZHUGH TALMAN, Professor in Charge of Library.

The subjoined titles have been selected from the contents of the periodicals and serials recently received in the Library of the Weather Bureau. The titles selected are of papers and other communications bearing on meteorology and cognate branches of science. This is not a complete index of the meteorological contents of all the journals from which it has been compiled. It shows only the articles that appear to the compiler likely to be of particular interest in connection with the work of the Weather Bureau.

American society of civil engineers. Proceedings. New York. v. 42. November, 1916.
Binckley, George S., & Lee, Charles H. Suggested changes and extension of the United States Weather Bureau service in California. Discussion by J. B. Lippincott. p. 1407–1411.
Duryea, Edwin, Jr., & Haehl, H. L. A study of the depth of annual evaporation from Lake Conchos, Mexico. Discussion by Edwin Duryea, jr., and H. L. Haehl. p. 1413–1474.

Engineering news. New York. v. 76. 1916.
Southern rains and floods of July, 1916, exhibited. p. 886–887. (Nov. 9.) [Abstract of paper by A. J. Henry.]
Chittenden, H. M. The battle over the Miami flood-prevention plans. p. 906–910. (Nov. 9.)
Hoff, E. J. Sensitive water-level recorder. p. 974–975. (Nov. 23.)

Nature. London. v. 98. November 16, 1916.
Shaw, Napier. Prof. Henrik Mohn. p. 211–212.
Meteorology in war. p. 216–217.

Science. New York. v. 44. November 17, 1916.
Greely, A[dolphus] W[ashington]. Cleveland Abbe. p. 703–704.
Trowbridge, C[harles] C. The focus of the auroral streamers on August 25, 1916. p. 717–722.

Scientific American. New York. v. 115. 1916.
Oil will not dissipate fog. p. 418. (Nov. 4.)
Professor Cleveland Abbe, 1838–1916. p. 437. (Nov. 11.) [Obituary.]

Scottish geographical magazine. Edinburgh. v. 32. November, 1916.
Chisholm, George G. Generalisations in geography, especially in human geography. p. 507–519. [Discusses reduction of temperature to sealevel, p. 508–510; comments unfavorably on isothermal charts involving such reduction.]

Terrestrial magnetism and atmospheric electricity. Baltimore. v. 21. September, 1916.
Knoche, W[alter A.] & Laub, J. Meteorologische und luftelektrische Messungen während der totalen Sonnenfinsternis am 10. Oktober 1912 auf der Facenda Boã Vista bei Christina, Brasilien. 1.—Meteorologische Beobachtungen. p. 117–144.

Symons's meteorological magazine. London. v. 51. October, 1916.
Professor Henrik Mohn. Bergen, 15th May, 1833–Kristiania, 15th September, 1916. p. 130. [Obituary.]
Edward Mawley. 1842–Berkhamsted, 15th September, 1916. p. 131. [Obituary.]

Académie des sciences. Comptes rendus. Paris. Tome 163. 1916.
Perot, A. Influence du vent sur les conditions d'audition du son. p. 272–273. (11 sept.)
Bigourdan, G[uillaume]. Sur la propagation à grande distance du bruit de la canonnade du front. p. 323–324. (2 oct.)
Garrigou-Lagrange, P. L'action luni-solaire et la température. p. 334–335. (2 oct.)
Vegard, L., & Krognes, O. Résultats d'observations d'aurores boréales exécutées à l'observatoire de Haldde. p. 442–446. (23 oct.)

Annalen der Hydrographie und maritimen Meteorologie. Hamburg. 44. Jahrgang. H. 8. 1916.
Sverdrup, H. U. Druckgradient, Wind und Reibung an der Erdoberfläche. p. 413–427.
Hackenbroich, Anton. Die unperiodischen Schwankungen des Luftdrucks und Regens im Tropengebiet des Atlantischen Ozeans. p. 427–441.
Schuster, F. Die Verschiebung des synodischen Luftdrucksystems unter dem Einfluss der 18.6-jährigen Mondperiode. p. 442–444.

Hemel en dampkring. Den Haag. October 1916.

Cannegieter, H. G. Temperatuur, luchtdruk en wind in de hoogere dampkringslagen. p. 87–91.

Sociedad cientifica "Antonio Alzate." Memorias y revista. Mexico. t. 34. Octubre 1916.

Romo, Ambrosio. El problema de la previsión del tiempo en las altas regiones intertropicales. p. 363–372.

Pontificia accademia romana dei Nuovi Lincei. Memorie. Roma. ser. 2. v. 1. 1915.

Negro, Carlo. Sul clima della Libia attraverso i tempi storici. Memoria 2. p. 197–263.

Reale società geografica. Bollettino. Roma. 1916.

Porro, Francesco. Perchè l'emisfero australe della terra sia più freddo del boreale. p. 430–432. (Maggio.)

Tascone, Giacomo L. Riassunto delle osservazioni meteorologiche eseguite all' Osservatorio Simbruino nel biennio 1914–1915 primo de sua fondazione. p. 468–486. (Giugno.)

Societa meteorologica italiana. Bollettino bimensuale. Torino. v. 35. Dicembre 1915–gennaio 1916.

Kahanosvich, Maria. Sulla meteorologia di Napoli. p. 1–8.

Negro, Carlo. Indovinelli e curiosità nel campo della meteor ologia. p. 8–9.

SECTION VII.—WEATHER AND DATA FOR THE MONTH.

THE WEATHER OF THE MONTH.

P. C. DAY, Climatologist and Chief of Division.

[Dated: Weather Bureau, Washington, Dec. 2, 1916.]

PRESSURE.

The distribution of the mean atmospheric pressure over the United States and Canada, and the prevailing direction of the winds are graphically shown on Chart VII, while the average values for the month at the several stations, with the departures from the normal, are shown in Tables I and III.

For the month as a whole the barometric pressure averaged above the normal throughout the whole country, except over the Florida Peninsula, where it was slightly below. The departures were generally not large, the pressure averaging but slightly above the normal throughout most southern, central, and north-central districts. The greatest plus departures appear in the northwest and northeast districts.

The month opened with relatively high pressure in the East and low pressure in the West. During the first half of the month it was generally high in most eastern districts, except for the occasional passage of a moderately low area. In the West and far Northwest after a few days of low pressure the first half of the month was generally above, while in the far Southwest it was slightly below the normal. About the 18th a tropical storm moved from the Gulf to the Great Lakes and caused low pressure in the eastern districts for several days. From the 23d to the 27th high pressures predominated in the Central Rocky Mountain and Plateau regions. The month closed with relatively high pressure in all sections except the extreme Northwest, the upper Lake region, and the Florida Peninsula, where it was below the average.

The distribution of the HIGHS and LOWS was generally favorable for northeasterly winds in the South Atlantic and East Gulf States, southerly and southwesterly in the New England and Middle Atlantic States, the Lake region, Ohio Valley, upper Mississippi and lower Missouri valleys, and southeast portion of the Great Plains States, and southeasterly in the West Gulf States. Elsewhere variable winds prevailed.

TEMPERATURE.

The month opened with cool weather in the Eastern States and warm weather in the Southwest, but by the 3d a marked rise in temperature reached the central valleys and extended to the eastward, and at the same time cold weather overspread Montana and the adjacent States. For the first 9 days of October the temperature averaged above the normal in northeastern districts, the central valleys, and the central Plains States, but it was below the average during this period in the far western districts, notably in the upper Missouri Valley.

From the 8th to the 10th of the month a fall in temperature occurred from the Plains Region eastward, and by the 10th cool weather prevailed in practically all the northern part of the country. However, during the next few days warmer weather set in over the Central Plains, gradually overspreading most central and eastern districts, and by the middle of the month quite warm weather for the season prevailed in the western part of the cotton belt. About the 18th cold weather again appeared over the northern plains, and spread southward with increasing intensity, and killing frosts occurred in Oklahoma and parts of Texas on the morning of the 20th. At the same time warm weather for the season still covered the Atlantic Coast States and eastern Lake Region. From the 10th to 19th, as a whole, the average temperature was above normal in the far Northwest and in the cotton States, but below the average in northeastern and southwestern districts. Cold weather overspread the eastern cotton States and to the northward on the 21st and 22d, with killing frosts in nearly all parts of Tennessee and portions of Mississippi and Alabama. Milder weather gradually followed and moderate temperature prevailed during the remainder of the month in most places, but it was rather warm for the season in the Central Plains, Central valleys, and the far Northwest, while cool weather predominated in the far southwestern districts. For the month, as a whole, the temperature was slightly above the normal in the central part of the country and somewhat below in the greater part of the West and the Northwest.

PRECIPITATION.

Fair weather prevailed in most eastern and central districts at the beginning of the month, and throughout the first week there was little precipitation, except in Florida and portions of the Southwest, where, especially in much of California and Nevada, the daily amounts were heavy for the season. About the 13–14th moderate rain fell in most districts north of the Ohio and Potomac rivers, the amounts being largest in parts of Michigan and northern New York and New England. About the middle of the month rains fell in southwestern Colorado and at several points in the southern Plains States. On the 17–18th a tropical storm caused high winds and much rain near the central and eastern Gulf coasts; the rainfall at Burrwood, La., for the 24 hours ending the morning of the 18th was 11.88 inches. As the storm passed northward to the Ohio Valley, heavy rains fell over practically the whole of the southeastern portion of the country on the 18th and 19th, and widespread rains of more moderate amounts occurred north of the Ohio River on the 19th and 20th. On the west side of the storm in Nebraska, Kansas, Iowa, and Illinois there was considerable snowfall for the season of the year.

During the last 10 days of the month there were few widespread storms, but about the 25th heavy rains occurred at points in northeastern Kansas, western Missouri, the upper Mississippi Valley, and upper Lake region, while on the 30th there were heavy falls in much of Georgia and eastern Florida.

For the month, as a whole, precipitation was heavy in the eastern Florida Peninsula, southeastern Louisiana, southwestern Colorado, and southeastern Utah. Rather large amounts for the season occurred in eastern Arkansas, northwestern Texas, the western portions of New Mexico and Wyoming, and northern California. Elsewhere

precipitation was generally light, with large areas in the Great Plains States having less than 1 inch, and much of eastern and central Washington and Oregon less than one-half inch of precipitation.

SNOWFALL.

A much larger extent of the country was visited by snowstorms than is usual for October, the southern limit of snow extending well into the central portions from the Ohio Valley westward to the mountains of California. From the 18th to 20th unusually heavy snows occurred over much of the lower Missouri and upper Mississippi valleys, the fall being especially heavy in portions of Nebraska, Iowa, and Minnesota. In the western mountain districts snow was reported from nearly all portions and over large areas from Montana southward over Wyoming, Colorado, Utah, and Nevada the amounts were unusually large.

Warmer weather following the snowfall soon caused it to disappear and at the end of the month but little remained on the ground, except in the higher mountains.

RELATIVE HUMIDITY.

For the month as a whole the relative humidity throughout the Great Plains States and to the westward was generally above the normal, except in Washington, Oregon, and the extreme western portions of Idaho and Montana, where the weather for the month was drier than usual. On the other hand the month was relatively damper than the average in much of the Mississippi and Ohio Valleys, the Lake region, the eastern Gulf and the Middle Atlantic States, save in portions of the Carolinas and Georgia, where it was drier. In the southern portions of the New England and Middle Atlantic States the relative humidity for the month averaged near or slightly above the normal.

GENERAL SUMMARY.

Mild weather, little rain, and much sunshine gave conditions favorable for the maturing and harvesting of late crops in most central and eastern districts. The seeding of winter grains was delayed on account of lack of moisture during the early part of the month in nearly all sections of the country, particularly in the Mississippi Valley States. However, the rains which occurred during the latter half of the month made possible the carrying on of this work, and excellent progress was made except in parts of the south central, north central, and extreme eastern districts. Seasonable temperature and abundance of sunshine were favorable for picking cotton, and this work progressed in a very satisfactory manner. There was not enough rain for pastures in some eastern States, but in most sections the pastures and ranges were favorably affected by moisture, and stock is reported in good condition in most western districts. Rainy weather in California during the early part of the month, while a benefit to the citrus fruit and fall truck, did great damage to the raisin crop which was on the drying trays. The hard freezes of the 9th and 19th caused severe loss of apples on trees in the Bitterroot Valley, Montana.

SEVERE STORMS.

The following notes of severe storms have been extracted from reports from officials of the Weather Bureau:

Alabama.—A tropical storm moved from the Gulf of Mexico northward over western Alabama and eastern Mississippi on October 18, 1916. The passage of this storm was marked by unprecedented high winds in the coast and southeastern counties. The maximum velocity at Mobile was 115 miles an hour from the east at 8:25 a. m., which is the highest record for the State. The damage along the Gulf coast was remarkably slight, considering the velocity of the wind, and appears to have been greatest in Dale, Coffee, and Covington Counties, where much timber was blown down, several houses demolished, and at least two persons killed.

Florida.—A tropical storm passed over Pensacola, Fla., on October 18, 1916, where the wind reached an extreme velocity of 120 miles an hour at 10:13 a. m., when the wind instrument tower was blown down. Many buildings were unroofed or demolished, but the damage to shipping interests was comparatively small because of precautions taken. The total damage was estimated at about $100,000.

Average accumulated departures for October, 1916.

Districts.	Temperature.			Precipitation.			Cloudiness.		Relative humidity.	
	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure for the current month.	Accumulated departure since Jan. 1.	General mean for the current month.	Departure from the normal.	General mean for the current month.	Departure from the normal.
	°F.	°F.	°F.	In.	In.	In.	P.ct.		P.ct.	
New England	51.9	+1.5	− 4.3	1.79	−1.80	− 3.80	4.9	−0.5	77	− 2
Middle Atlantic	56.2	+0.5	+ 6.3	1.51	−1.70	− 4.70	4.2	−0.6	74	− 2
South Atlantic	64.5	+0.8	+ 9.2	3.20	−0.70	−10.20	4.8	+0.8	79	+ 1
Florida Peninsula	77.2	+0.8	− 1.8	3.06	−3.20	−13.10	4.9	+0.2	78	− 2
East Gulf	66.6	+1.0	+ 7.6	2.50	−0.30	− 1.20	3.2	−0.7	72	− 1
West Gulf	68.0	+1.3	+12.7	1.51	−1.30	− 5.80	3.0	−0.7	69	− 3
Ohio Valley and Tennessee	57.5	+0.9	+ 1.7	2.20	−0.30	− 0.60	3.8	−0.6	70	− 1
Lower Lakes	52.2	+0.5	+ 0.1	2.37	−0.90	− 2.10	4.9	−1.0	70	− 4
Upper Lakes	47.6	+0.1	+ 0.8	3.42	+0.60	+ 2.50	5.9	−0.1	76	− 2
North Dakota	40.5	−2.0	−17.6	0.47	−0.80	+ 0.10	5.7	+0.5	74	+ 2
Upper Mississippi Valley	53.2	+0.2	+ 3.0	2.27	−0.20	− 1.20	4.9	+0.3	72	+ 1
Missouri Valley	53.1	+4.1	+ 7.4	1.52	−0.40	− 5.90	4.4	+0.3	66	− 1
Northern slope	42.1	−2.6	−13.4	1.76	+0.50	+ 0.40	5.2	+0.8	68	+ 8
Middle slope	55.5	0.0	+ 4.0	1.42	−0.10	− 4.10	4.0	+0.6	63	+ 4
Southern slope	62.7	+0.3	+15.4	2.24	+0.40	− 4.00	3.0	−1.6	64	+ 1
Southern Plateau	57.5	−2.3	− 3.4	1.06	+0.50	+ 1.50	2.2	0.0	52	+10
Middle Plateau	47.5	−3.3	− 5.8	1.78	+1.00	+ 1.20	3.2	−0.1	58	+ 9
Northern Plateau	47.9	−1.6	−16.5	0.66	−0.90	+ 0.80	3.8	−0.8	55	− 8
North Pacific	50.0	−1.7	− 7.7	1.81	−2.20	− 8.30	5.1	−1.2	78	− 2
Middle Pacific	55.1	−3.6	− 3.0	1.01	−0.60	− 0.10	4.7	+0.9	71	+ 1
South Pacific	59.0	−3.2	− 4.6	1.64	+0.80	+ 5.90	4.1	+1.0	76	+ 6

WEATHER CONDITIONS ON THE NORTH ATLANTIC DURING OCTOBER, 1915.

The data presented are for October, 1915, and comparison and study of the same should be in connection with those appearing in the REVIEW for that month.

Chart IX (XLIV—133) shows for October, 1915, the averages of pressure, temperature, and the prevailing direction of the wind at 7 a. m., 75th Meridian time (Greenwich Mean Noon), together with the locations and courses of the more severe storms of the month.

PRESSURE.

The distribution of the average pressure for the month, as shown on Chart IX, differed but slightly from the normal over the greater part of the ocean, although unusual conditions existed in the region shown in the extreme northeastern part of the chart. The Azores HIGH was practically normal as to extent and position, and slightly above in intensity, while the Continental HIGH

with a crest of 30.19 inches was central in eastern Kentucky, extending as far east as the 75th Meridian. The Icelandic LOW of 29.65 inches was well developed and somewhat south of its normal position, the approximate center being near latitude 62°, longitude 28°.

The most unusual feature of the monthly distribution was the high-pressure area, with a crest of 30.24 inches, central near Christiania, Norway, where the normal for the month is about 29.80 inches. The steep gradient between this HIGH and the Icelandic LOW was responsible for the unusually large number of days on which winds of gale force were reported from the region between these two areas. In the 5-degree square that includes the crest of the HIGH just referred to, the variation in pressure from day to day was comparatively small, the pressure ranging from 29.90 inches on the 1st, to 30.58 inches on the 19th. On every day during this period readings were above the monthly normal, and on only two days did they fall below 30 inches.

In the territory covered by the Icelandic LOW the conditions were reversed, as the fluctuations in the pressure readings during the month were marked, the extreme pressures were 28.80 inches on the 13th, 30.30 inches on the 25th. In this square the pressure was considerably below the monthly mean from the 11th to the 17th, and on the 27th and 28th, while it was above the average on the 19th, 20th, 25th, and 26th, the departures being small during the remainder of the month. In the waters adjacent to the European coast high pressure prevailed between the 3d and 6th, and on the 17th and 19th, while it was low on the 10th, 11th, 28th, and 31st. Off the American coast the highest barometric readings were recorded on the 11th and 12th, and the lowest on the 2d; the readings, as a rule, were uniformly high, and the variations from day to day small.

GALES.

Under normal conditions there is a considerable increase in the number of gales in October as compared with September. For October, 1915, the number reported between the 45th and 55th parallels and the 10th and 25th meridians, was considerably above the normal for the month. In the 5-degree square between latitude 50°–55°, longitude 20°–25°, they were reported on 9 days, a percentage of 29, the normal for that square being 19. In the middle portion of the northern steamer routes, the percentage ranged from 10 to 19, which in some localities was slightly above the normal, and in others below. The waters along the American coast were remarkably free from heavy winds, the same conditions holding true in the Caribbean Sea and Gulf of Mexico.

On Chart III, tracks of centers of low areas, October, 1915 (XLIII–117), a LOW (1 on Chart IX) is shown that on the morning of the 1st was near Charlotte, N. C. This moved rapidly in a northeasterly direction and on the evening of the same day was a short distance east of Norfolk. It decreased somewhat in its rate of movement and on the morning of the 2d was central about 100 miles east of Cape May; the winds were from moderate to fresh, with a minimum barometer reading of 29.68 inches. The LOW then moved in a due easterly direction and on the morning of the 3d was near latitude 40°, longitude 64°, the general conditions having changed but little since the previous day. Continuing in its easterly course with an increased rate of movement, the disturbance reached a point near latitude 40°, longitude 51°, on the 4th. While the barometer readings remained practically unchanged, the winds had increased somewhat in velocity, a number of vessels reporting gales of from 40 to 48 miles an hour. This LOW then turned toward the southeast and, diminishing somewhat in speed, was central on the 5th near latitude 36°, longitude 45°; the barometer had risen slightly since the 4th, although gales were reported in the northwest quadrant. There was a HIGH of 30.10 inches on this day, with its center near Halifax, and the steep gradient between the two areas caused heavy winds in the intermediate territory. While traces of the LOW could be seen on the 6th, it was fast filling in, light to moderate winds prevailing. On October 6 there was a well-developed LOW of 29.50 inches central near latitude 48°, longitude 26°, that was accompanied by moderate to fresh winds, while fog was encountered near the center. This moved in a northeasterly direction, and on the 7th the approximate center was near latitude 57°, longitude 16° W., although the area had increased so in extent and so few observations were received that it was difficult to plot its location accurately. The barometer had risen slightly since the day before, and the force of the wind remained about stationary, except that one vessel off the south coast of Ireland reported a southerly gale of 40 miles an hour.

From the 8th to the 12th the LOW was apparently stationary in the vicinity of Iceland, although its position was indeterminate on account of the lack of observations. On October 11 there was a LOW of 29.51 inches (11 on Chart IX) central about 100 miles southeast of Saint Johns, N. F. Moderate winds, with thick fog, prevailed near the center, while in the southwest quadrant of the area gales of from 40 to 55 miles were reported. On the same day a HIGH with a crest of 30.20 inches was located a short distance west of the Azores, and winds of gale force prevailed in the region between the two areas. The LOW area moved in a northeasterly direction, and on the 12th the center was near latitude 48°, longitude 39°; the barometer had fallen to 28.96 inches, and the winds increased in violence, as gales of from 50 to 70 miles an hour prevailed over a large portion of the territory between the 40th and 52d parallels and the 35th and 48th meridians, while hail was reported by two vessels.

The course of the storm curved slightly toward the north, and on the 13th the center was near latitude 48°, longitude 23°; the barometer had fallen to 28.60 inches, and the force of the wind and extent of the storm area had apparently changed but little since the previous day. From the 14th to the 17th there were indications of a LOW in the vicinity of Iceland, although its position could not be determined accurately on account of the few observations received from that vicinity. On the 18th there was a disturbance, with the lowest barometer reading of 29.14 inches at latitude 55°, longitude 44°. Strong gales were encountered to the eastward and southward of this point, and one vessel at latitude 55°, longitude 35°, reported a southerly gale with a maximum force of 75 miles an hour. While the storm area was somewhat larger than on the day before, there was quite a variation in the wind velocities as reported from different vessels in that region, as they ranged from 23 to 75 miles an hour.

This disturbance moved in an easterly direction and on the 19th was central near latitude 53°, longitude 30°; the barometer had risen to 29.60 inches, and the maximum wind velocity, as recorded by three vessels near the 30th Meridian and between the 47th and 57th parallels, was 48 miles an hour. From the 20th to the 22d this LOW remained nearly stationary, the winds decreasing in

force, and by the 23d only faint traces of it were observed, On the 24th there was a well-defined area of low pressure off the south coast of Newfoundland with a minimum barometer reading of 29.34 inches, and moderate winds. This moved toward the northeast, apparently decreasing in intensity, and by the 25th the approximate center was near latitude 55°, longitude 45°; one vessel reported a westerly gale of 48 miles, although there were too few observations in the vicinity to determine the conditions accurately. On October 27 a LOW of 29.24 inches was located near latitude 59°, longitude 19°, and on the same day a HIGH with a crest of 30.61 inches existed off the Canadian coast near the 50th Meridian. No heavy winds were encountered near the center of the LOW, but in the territory between the two areas, near the 49th parallel and the 27th Meridian, three vessels reported northwesterly gales of 48 miles an hour, while the barometer readings ranged from 29.94 inches to 30.20 inches. On the 28th the center of the LOW had remained practically stationary and of the same intensity, but had increased somewhat in extent. The HIGH was on that date a short distance northwest of the Azores, the barometer reading at the crest having fallen to 30.50 inches. As on the previous day most of the heavy winds reported occurred about midway between the two areas, where northwest gales of from 40 to 55 miles prevailed.

During the 29th and 30th there was not a great deal of change in the relation of the HIGH and LOW as compared with the 28th, although on the 30th the LOW was about 5° south of its former position, and was accompanied by westerly and northwesterly gales of from 40 to 65 miles an hour, while fog prevailed near its center. This LOW then moved rapidly toward the southeast, and on the 31st was central near Brest, France, where the barometer reading was 29.27 inches. Strong northwest gales still prevailed between the French coast and the 22d Meridian, and the storm area remained about the same in extent as on the previous day.

On the 30th a second LOW of 29.42 inches covered a large portion of the Province of Quebec. While this depression was very definite in outline, it was accompanied only by light and moderate winds, and fog prevailed in its eastern portion. This LOW moved toward the east, and on the 31st was central near the intersection of the 50th parallel and 60th Meridian, the barometer having fallen to 28.98 inches. One vessel, about 200 miles southwest of the center, encountered a northwest gale of over 50 miles an hour, and another ship as far south as latitude 36° had the same experience, while moderate winds, and fog, were reported from the territory between.

TEMPERATURE.

The average monthly temperature of the air over the ocean was as a whole, slightly lower than usual. South of the 50th parallel the departures ranged from 0° to −3°, while north of that parallel and in the waters adjacent to the European coast they were slightly positive. While the temperature over the western part of the ocean and Gulf of Mexico was slightly below the normal, it rose as the shore was approached, as positive departures prevailed for the most part at a number of Canadian and United States Weather Bureau stations on the Atlantic and Gulf coasts, as shown by the following table:

	°F.		°F.
St. Johns, N. F.	+0.6	Washington, D. C.	+2.0
Sydney, C. B. I.	+3.2	Norfolk, Va.	+3.1
Halifax, N. S.	+2.8	Hatteras, N. C.	+2.4
Eastport, Me.	+2.0	Charleston, S. C.	+3.7
Portland, Me.	+2.1	Key West, Fla.	+2.2
Boston, Mass.	+3.4	Tampa, Fla.	+4.2
Nantucket, Mass.	+0.3	New Orleans, La.	+3.9
Block Island, R. I.	−0.1	Galveston, Tex.	+1.8
New York, N. Y.	+1.1	Corpus Christi, Tex.	+1.9

The lowest temperature recorded during the month was 35°, and occurred on the 25th in the 5-degree square between the 50th and 55th parallels and the 55th and 60th Meridians, while the highest temperature for the same square was 49° on the 9th and again on the 14th.

FOG.

During the period from 1901 to 1906 for the month of October the average percentage of days with fog off the banks of Newfoundland was 30, while in the same region for October, 1916, it was observed on 7 days, a percentage of 23. In the vicinity of Cape Cod and Nantucket the amount was considerably below the normal, while over the central part of the northern steamer routes it was slightly above.

PRECIPITATION.

Hail was observed in mid-ocean on the 12th, 18th, and 28th, and on the last date it was also reported off the Irish coast. No snow was reported during the month.

Maximum wind velocities, October, 1916.

[Velocities below 50 *mis/hour* (22.4 *m/sec.*) are not included here.]

Stations.	Date.	Velocity.	Direction.	Stations.	Date.	Velocity.	Direction.
		Mis/hr.				*Mis/hr.*	
Alpena, Mich.	16	52	nw.	New York, N. Y.	17	63	nw.
Block Island, R.I.	14	56	nw.	Do.	19	60	s.
Do.	17	57	nw.	North Head, Wash.	28	72	se.
Buffalo, N. Y.	13	68	sw.	Do.	29	72	s.
Do.	16	68	sw.	Do.	30	70	s.
Do.	17	66	w.	Pensacola, Fla.	18	120	w.
Do.	20	61	w.	Point Reyes Light, Cal.	2	54	nw.
Do.	21	61	sw.	Do.	27	58	nw.
Do.	25	70	w.	Portland, Me.	13	54	nw.
Do.	26	66	w.	Do.	14	63	nw.
Do.	27	50	w.	Do.	17	62	sw.
Canton, N. Y.	17	54	w.	Do.	19	62	se.
Cheyenne, Wyo.	1	53	w.	Do.	20	56	se.
Detroit, Mich.	20	54	sw.	Providence, R. I.	17	60	nw.
Do.	25	52	sw.	Saint Paul, Minn.	16	52	nw.
Duluth, Mich.	16	54	nw.	Sandy Hook, N. J.	19	54	s.
Erie, Pa.	19	61	se.	Do.	20	50	s.
Green Bay, Wis.	16	52	nw.	San Juan, P. R.	9	52	n.
Louisville, Ky.	20	50	sw.	Seattle, Wash.	29	51	s.
Lynchburg, Va.	18	63	ne.	Syracuse, N. Y.	17	50	nw.
Mobile, Ala.	18	115	e.	Tatoosh Island, Wash.	28	76	s.
Mount Tamalpais, Cal.	2	57	nw.	Do.	30	74	s.
Do.	3	56	nw.	Do.	31	54	sw.
Do.	27	50	nw.	Toledo, Ohio.	20	60	nw.
Do.	28	54	nw.	Do.	25	54	sw.
Do.	30	51	nw.				
New York, N. Y.	9	51	nw.				
Do.	14	58	nw.				

CONDENSED CLIMATOLOGICAL SUMMARY.

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, October, 1916.

Section.	Temperature.							Precipitation.					
	Section average.	Departure from the normal.	Monthly extremes.					Section average.	Departure from the normal.	Greatest monthly.		Least monthly.	
			Station.	Highest.	Date.	Station.	Lowest. Date.			Station.	Amount.	Station.	Amount.
	°F.	°F.		°F.			°F.	In.	In.		In.		In.
Alabama	64.8	+0.7	Auburn	97	9	2 stations	26 22	1.74	−0.88	Robertsdale	5.00	Scottsboro	0.00
Arizona	59.5	−1.6	3 stations	96	3†	Alpine	12 26	2.00	+0.75	Alpine	8.67	3 stations	0.00
Arkansas	62.8	+1.1	Brinkley	96	7	2 stations	21 21	2.30	−0.70	Centerpoint	5.06	Bergman	0.72
California	55.0	−6.1	2 stations	98	1†	Summit	10 5	1.91	+0.46	Yosemite	8.71	12 stations	0.00
Colorado	44.8	−1.1	Lamar	96	7	Spicer	−10 22	2.71	+0.98	Cascade	9.10	Yoder	0.04
Florida	73.5	+0.5	Malabar	95	19	2 stations	34 22	4.13	+0.04	Homestead	14.34	Tampa	0.77
Georgia	65.3	+1.0	Bainbridge	94	16	2 stations	28 22	2.14	−0.76	Savannah	4.94	Putnam	0.70
Hawaii [September]	73.5	−0.8	Mahukona, Hawaii	95	7	Volcano Observatory.	52 3†	4.78	−1.19	Mount Eke, Maui	25.40	Waiopae ranch, Maui.	0.00
Idaho	43.3	−2.6	Guffey	87	1	2 stations	1 21†	1.22	−0.13	Spencer	3.21	Hotspring	0.21
Illinois	55.2	+0.5	Albion	93	8	3 stations	23 11†	2.95	+0.42	Joliet	5.18	Cairo	1.29
Indiana	54.5	−0.2	Rome	97	7	Rome	21 22	2.13	−0.50	Columbus	3.84	Greenfield	0.69
Iowa	50.9	+0.1	Toledo	92	7	2 stations	11 21	2.00	−0.46	Clinton	4.33	Lake Park	0.20
Kansas	57.4	+0.7	2 stations	97	3†	Blakeman	9 20	1.72	−0.26	Lawrence	3.86	Irene	0.37
Kentucky	57.6	−0.1	Earlington	97	7	5 stations	24 22	2.59	+0.31	Eubank	4.99	Princeton	1.29
Louisiana	67.8	+0.4	Angola	100	9	2 stations	30 21†	3.77	+0.97	Burrwood	14.60	Vinton	0.27
Maryland-Delaware	55.6	−0.9	Western Port, Md.	91	6	Oakland, Md	19 27	1.90	−1.17	Emmitsburg, Md	4.05	Coleman, Md	0.63
Michigan	48.1	−0.5	2 stations	89	5†	Humboldt	11 24	3.59	+0.94	Mancelona	6.57	Eagle Harbor	1.70
Minnesota	43.2	−2.2	2 stations	88	7	Argyle	−1 20	1.29	−0.93	Baudette	2.97	Beardsley	0.15
Mississippi	64.7	+0.7	2 stations	97	9	Fortersville	26 22	2.04	−0.21	Pearlington	7.25	Macon	0.58
Missouri	58.0	+0.7	Lamar	95	5	Oregon	20 20†	2.17	−0.54	Liberty	4.86	Birchtree	0.48
Montana	40.4	−3.4	Glacier Park	86	16	Ringling	− 6 19	1.17	+0.14	Red Lodge	4.06	Deer Lodge	0.05
Nebraska	50.4	−0.5	Cambridge	100	3	2 stations	6 19†	1.16	−0.42	Lexington	2.96	O'Neill	0.38
Nevada	46.3	−3.2	Las Vegas	88	18	Elko	8 19	1.68	+1.25	Lamoille	5.21	Searchlight	0.13
New England	50.5	+1.8	Nashua, N. H.	87	5	Voluntown, Conn	17 18	1.94	−1.60	Patten, Me	4.70	Lawrence, Mass	0.92
New Jersey	55.1	+1.1	Tuckerton	92	9	Charlotteburg	23 27	1.37	−2.34	South Orange	2.38	Newton	0.51
New Mexico	52.9	+0.3	2 stations	95	3†	2 stations	12 20†	2.74	+1.59	Hood ranger station	6.57	Nara Visa	0.31
New York	50.5	+0.6	Rome	89	4	North Lake	14 18	2.10	−1.26	Fredonia	4.67	New York	0.63
North Carolina	60.6	+0.9	Greensboro	92	9	Andrews	22 22	3.15	−0.02	Settle	7.10	Pinehurst	1.19
North Dakota	40.0	−3.8	Carson	85	1	3 stations	− 2 20	0.68	−0.36	Pembina	2.06	Lisbon	T.
Ohio	53.2	−0.2	3 stations	93	6†	2 stations	22 26†	2.12	−0.42	Milton Dam	3.52	Mount Healthy	1.05
Oklahoma	62.4	+0.07	Goodwell	100	3	2 stations	19 20	2.34	−0.25	Hobart	5.18	Goodwell	0.12
Oregon	48.5	−2.6	Prospect	94	16	Beckley	4 23	0.82	−1.81	Welches	3.07	Merrill No. 2	0.00
Pennsylvania	52.1	+0.1	2 stations	92	8	Mount Pocono	16 17	2.25	−1.02	Warren	4.45	Bethlehem	0.76
Porto Rico	78.2	0.0	Mayaguez	99	26†	2 stations	59 4†	13.02	+4.08	Foro Negro Dam	23.81	Camuy	4.15
South Carolina	64.1	+0.8	3 stations	92	9†	Mountain Rest	31 21†	2.54	−0.64	Centenary	6.96	Edgefield	0.88
South Dakota	45.2	−2.7	5 stations	92	3	2 stations	6 20†	0.71	−0.57	Waters ranch	2.30	Britton	T.
Tennessee	59.7	+0.7	2 stations	95	7	Crossville	22 23	2.72	+0.05	Florence	5.37	Johnson City	1.18
Texas	68.2	+1.2	Coleman	101	5	Dalhart	17 20	2.07	−0.76	Quanah	5.84	3 stations	0.00
Utah	46.2	−1.9	St. George	84	5	Blacks Fork	0 19	2.90	+1.84	Monticello	7.25	Jozella Ranch	0.09
Virginia	57.5	+0.2	2 stations	94	8†	Burkes Garden	19 27	2.21	−0.94	Rocky Mount	3.41	Dry Bridge	1.15
Washington	48.0	−1.6	Maryhill	88	1	Deer Park	12 22†	1.35	−1.45	Forks	8.94	5 stations	0.00
West Virginia	54.1	−0.4	Moorefield	97	8	Marlinton	16 27	2.38	−0.26	Lost Creek	4.35	Sissonville	0.91
Wisconsin	47.0	−0.9	Prairie du Chien	88	8	Hayward No. 2	12 17†	3.23	+0.88	Sturgeon Bay	5.34	Superior	1.08
Wyoming	40.3	−2.2	Lagrange	85	1	Painter	−10 19	1.63	+0.62	Yellowstone Park	3.47	Lovell	0.22

† Other dates also.

DESCRIPTION OF TABLES AND CHARTS.

Table I gives the data ordinarily needed for climatological studies for about 158 Weather Bureau stations making simultaneous observations at 8 a. m. and 8 p. m., daily, 75th Meridian Time, and for about 41 others making only one observation. The altitudes of the instruments above ground are also given.

Table II gives a record of precipitation, the intensity of which at some period of the storm's continuance equaled or exceeded the following rates:

Duration (minutes)	5	10	15	20	25	30	35	40	45	50	60
Rates per hour (inches)	3.00	1.80	1.40	1.20	1.08	1.00	0.94	0.90	0.87	0.84	0.08

It is impracticable to make this table sufficiently wide to accommodate on one line the record of accumulated falls that continue at an excessive rate for several hours. In this case *the record is broken at the end of each 50 minutes*, the accumulated amounts being recorded on successive lines until the excessive rate ends.

In cases where no storm of sufficient intensity to entitle it to a place in the full table has occurred the greatest precipitation of any single storm has been given, also the greatest hourly fall during that storm.

The tipping-bucket mechanism is *dismounted* and removed when there is danger of snow or water freezing in the same. Table II records this condition by entering an asterisk (*).

Table III gives, for about 30 stations of the Canadian Meteorological Service, the means of pressure and temperature, total precipitation and depth of snowfall, and the respective departures from normal values except in the case of snowfall.

Chart I.—Hydrographs for several of the principal rivers of the United States.

Chart II.—Tracks of centers of high areas; and

Chart III.—Tracks of centers of low areas. The roman numerals show the chronological order of the centers. The figures within the circles show the days of the month; the letters *a* and *p* indicate, respectively, the observations at 8 a. m. and 8 p. m., 75th Meridian Time. Within each circle is also given (Chart II) the last three figures of the highest barometric reading, or (Chart III) the lowest reading, reported at or near the center at that time, and in both cases as reduced to sealevel and standard gravity.

Chart IV.—Temperature departures. This chart presents the departures of the monthly mean temperatures from the monthly normals. The normals used in computing the departures were computed for a period of 33 years (1873 to 1905) and are published in Weather Bureau Bulletin "R," Washington, 1908. Stations whose records were too short to justify the preparation of normals in 1908 have been provided with normals as adequate records became available, and all have been reduced to the 33-year interval 1873–1905. The shaded portions of the chart indicate areas of positive departures and unshaded portions indicate areas of negative departures. Generalized lines connect places having approximately equal departures of like sign. This chart of monthly temperature departures in the United States was first published in the MONTHLY WEATHER REVIEW for July, 1909.

Chart V.—Total precipitation. The scale of shades showing the depth is given on the chart. Where the monthly amounts are too small to justify shading and over sections of the country where stations are too widely separated or the topography is too diversified to warrant reasonable accuracy in shading, the actual depths are given for a limited number of representative stations. Amounts less than 0.005 inch are indicated by the letter T, and no precipitation by 0.

Chart VI.—Percentage of clear sky between sunrise and sunset. The average cloudiness at each Weather Bureau station is determined by numerous personal observations between sunrise and sunset. The difference between the observed cloudiness and 100 is assumed to represent the percentage of clear sky, and the values thus obtained are the basis of this chart. The chart does not relate to the nighttime.

Chart VII.—Isobars and isotherms at sealevel and prevailing wind directions. The pressures have been reduced to sealevel and standard gravity by the method described by Prof. Frank H. Bigelow on pages 13–16 of the REVIEW for January, 1902. The pressures have also been reduced to the mean of the 24 hours by the application of a suitable correction to the mean of the 8 a. m. and 8 p. m. readings at stations taking two observations daily, and to the 8 a. m. or the 8 p. m. observation, respectively, at stations taking but a single observation. The diurnal corrections so applied will be found in the Annual Report of the Chief of the Weather Bureau, 1900–1901, volume 2, Table 27, pages 140–164.

The isotherms on the sealevel plane have been constructed by means of the data summarized in chapter 8 of volume 2 of the annual report just mentioned. The correction, t_0-t or temperature on the sealevel plane minus the station temperature as given by Table 48 of that report, is added to the observed surface temperature to obtain the adopted sealevel temperature.

The prevailing wind directions are determined from hourly observations at the great majority of the stations; a few stations having no self-recording wind-direction apparatus determine the prevailing direction from the daily or twice-daily observations only.

Chart VIII.—Total snowfall. This is based on the reports from regular and cooperative observers and shows the depth in inches and tenths of the snowfall during the month. In general, the depth is shown by lines inclosing areas of equal snowfall, but in special cases figures are also given. Chart VIII is published only when the general snow cover is sufficiently extensive to justify its preparation.

Chart IX.—Average values of pressure, temperature, and prevailing wind directions, and storm tracks over the North Atlantic Ocean, *for the corresponding month of last year.*

TABLE I.—*Climatological data for Weather Bureau Stations, October, 1916.*

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.					
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*		°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
New England.							**51.9**	**+ 1.5**											**77**	**1.79**	**− 1.8**									**4.9**		
Eastport	76	67	85	30.00	30.09	+0.09	48.4	+ 1.8	73	6	56	30	18	41	29		44	40	78	2.73	− 1.1	8	7,296	s.	46	se.	20	11	9	11	5.5	.....	.....
Greenville	1,070	6	....	28.90	30.08	.....	45.7	.....	81	5	57	22	19	35	40		.....	.....	.....	2.87	.....	7	.....	.....	.....	.....	.....	.....	.....	.....	.....	0.5	.....
Portland, Me.	103	82	117	30.01	30.13	+ .09	50.4	+ 1.3	79	6	59	32	18	42	31		45	39	70	1.29	− 2.4	10	11,497	sw.	63	nw.	14	15	7	9	4.4	.....	.....
Concord	288	70	79	29.82	30.14	+ .09	49.6	+ 0.9	83	5	63	27	27	36	44		.....	.....	.....	1.34	− 1.9	7	3,772	n.	40	w.	17	14	7	10	5.0	.....	.....
Burlington	404	11	48	29.67	30.12	+ .08	48.2	+ 1.3	76	5	58	27	18	38	32		.....	.....	.....	1.43	− 1.7	10	8,993	s.	48	s.	13	10	11	10	5.2	T.	.....
Northfield	876	12	60	29.17	29.13	+ .09	45.8	+ 2.2	82	5	60	23	23	32	49		40	37	80	2.09	− 0.4	8	5,708	s.	46	sw.	17	10	13	8	5.3	0.1	.....
Boston	125	115	188	29.99	30.13	+ .08	55.5	+ 3.2	84	8	64	36	18	47	36		50	46	75	0.94	− 2.9	7	7,489	sw.	42	nw.	17	14	9	8	4.4	.....	.....
Nantucket	12	14	90	30.12	30.13	+ .08	54.6	+ 0.1	70	9	61	39	18	48	23		51	48	82	1.92	− 1.5	10	12,812	sw.	48	sw.	13	12	8	11	5.7	.....	.....
Block Island	26	11	46	30.11	30.14	+ .09	55.1	− 0.2	72	9	61	39	18	49	22		52	49	82	2.48	− 1.6	8	12,568	ne.	57	nw.	17	15	4	12	5.2	.....	.....
Narragansett Pier	.....	9	.....	.....	.....	.....	52.7	+ 0.6	74	9	62	30	18	44	32		.....	.....	.....	2.78	.....	10	.....	ne.	.....	.....	.....	17	4	10	.....	.....	.....
Providence	160	215	251	29.96	30.13	+ .08	53.9	+ 1.7	83	9	64	33	18	44	38		49	46	77	2.39	− 1.4	7	9,239	sw.	60	nw.	17	13	11	7	4.5	.....	.....
Hartford	159	122	140	29.96	30.13	+ .07	53.8	+ 2.6	83	8	65	33	18	43	36		47	42	72	1.08	− 2.8	5	5,388	s.	37	nw.	17	13	9	9	4.7	.....	.....
New Haven	106	117	155	30.03	30.15	+ .09	55.2	+ 2.4	84	9	66	36	18	45	36		49	46	75	2.05	− 1.9	5	7,105	n.	38	s.	19	14	10	7	3.8	.....	.....
Middle Atlantic States.							**56.2**	**+ 0.5**											**74**	**1.51**	**− 1.7**									**4.2**		
Albany	97	102	115	30.02	30.13	+0.07	51.4	+ 1.0	77	6	62	31	27	41	30		46	42	76	1.54	− 1.4	6	5,204	s.	35	se.	13	15	8	8	4.7	.....	.....
Binghamton	871	10	69	29.21	30.15	+ .09	50.9	+ 1.7	84	8	64	26	27	38	41		.....	.....	.....	1.82	− 1.3	6	3,253	e.	26	w.	17	11	11	9	4.9	.....	.....
New York	314	414	454	29.80	30.14	+ .08	57.2	+ 1.6	84	9	65	39	10	50	34		50	44	67	0.63	− 3.1	3	11,804	nw.	63	nw.	15	15	7	9	4.3	.....	.....
Harrisburg	374	94	104	29.76	30.17	+ .09	54.4	+ 0.4	85	8	65	34	18	44	34		48	43	72	1.90	− 1.0	7	3,978	nw.	28	n.	9	18	6	7	3.6	.....	.....
Philadelphia	117	123	190	30.04	30.17	+ .10	58.6	+ 2.3	86	9	68	40	1	50	32		51	45	67	1.21	− 1.9	3	7,099	sw.	35	n.	10	16	8	7	4.0	.....	.....
Reading	325	81	98	29.81	30.17	+ .10	54.9	.....	84	8	66	33	18	44	35		48	43	72	1.24	− 2.0	4	4,416	sw.	31	se.	19	18	6	7	3.8	.....	.....
Scranton	805	111	119	29.28	30.16	+ .10	52.2	+ 0.8	81	8	64	30	27	40	38		46	42	76	0.91	− 2.0	7	4,714	sw.	36	w.	17	13	11	7	4.9	.....	.....
Atlantic City	52	37	48	30.10	30.16	+ .09	56.7	− 0.7	77	9	63	40	22	50	26		53	49	76	1.28	− 2.0	4	6,047	sw.	28	s.	19	14	7	10	4.7	.....	.....
Cape May	18	13	49	30.16	30.18	+ .11	57.5	− 2.1	82	9	65	39	18	50	26		53	.....	.....	0.90	− 2.4	7	6,361	ne.	34	se.	19	13	12	6	4.3	.....	.....
Sandy Hook	22	10	57	30.12	30.14	.....	57.4	.....	84	9	64	43	18	51	29		52	48	74	0.92	.....	4	11,491	s.	54	s.	19	17	8	6	3.9	.....	.....
Trenton	190	159	183	29.94	30.14	.....	56.1	.....	84	9	66	36	1	46	34		49	44	72	0.96	− 2.4	4	8,081	n.	44	nw.	17	14	11	6	3.9	.....	.....
Baltimore	123	100	113	30.03	30.16	+ .08	57.6	+ 0.1	86	8	67	40	1	48	28		51	46	71	1.61	− 1.4	7	4,770	n.	27	n.	10	17	6	8	3.9	.....	.....
Washington	112	62	85	30.03	30.15	+ .07	56.6	0.0	87	8	68	35	27	45	32		50	46	75	1.76	− 1.3	9	3,967	n.	26	sw.	20	17	8	6	3.9	.....	.....
Lynchburg	681	153	188	29.41	30.16	+ .07	57.7	+ 0.8	89	7	71	33	11	45	36		49	45	72	2.22	− 1.2	6	4,545	n.	63	ne.	18	17	8	6	4.6	.....	.....
Norfolk	91	170	205	30.04	30.14	+ .07	63.0	+ 1.7	86	9	69	44	15	57	23		57	53	76	2.62	− 1.3	4	10,505	ne.	44	s.	19	10	14	7	4.8	.....	.....
Richmond	144	11	52	30.00	30.16	+ .08	60.2	+ 0.4	90	9	72	37	12	49	35		53	49	76	1.44	− 1.9	4	5,875	ne.	32	s.	20	14	8	9	4.3	.....	.....
Wytheville	2,293	49	55	27.77	30.16	+ .07	52.6	− 1.0	81	8	65	29	27	40	35		47	44	81	2.18	− 1.0	9	3,697	nw.	29	w.	13	16	8	7	3.7	.....	.....
South Atlantic States.							**64.5**	**+ 0.8**											**79**	**3.20**	**− 0.7**									**4.8**		
Asheville	2,255	70	84	27.79	30.15	+0.06	56.3	+ 1.0	80	7	68	33	22	44	39		49	45	76	2.86	− 0.1	9	5,832	se.	48	e.	18	16	8	7	3.8	.....	.....
Charlotte	773	153	161	29.29	30.13	+ .05	61.0	− 0.1	85	9	71	39	11	51	26		54	49	71	2.64	− 0.5	6	8,864	ne.	46	sw.	20	15	10	6	3.7	.....	.....
Hatteras	11	12	50	30.10	30.10	+ .04	66.5	+ 0.5	79	9	71	50	15	62	18		62	60	83	4.16	− 1.8	9	12,318	ne.	48	n.	10	9	9	13	5.8	.....	.....
Manteo	12	4	46	.....	.....	.....	64.5	.....	83	9	71	42	15	58	.....		.....	.....	.....	1.84	− 4.2	4	.....	ne.	.....	.....	.....	14	6	11	.....	.....	.....
Raleigh	376	103	110	29.73	30.13	+ .06	61.8	+ 1.3	85	9	72	38	11	52	30		55	51	74	2.08	− 1.4	5	6,486	ne.	28	sw.	20	16	8	7	4.0	.....	.....
Wilmington	78	81	91	30.01	30.09	+ .03	65.0	+ 1.7	85	9	74	43	11	57	25		60	58	86	5.12	+ 1.4	7	7,018	ne.	32	ne.	4	13	8	10	4.7	.....	.....
Charleston	48	11	92	30.01	30.06	.00	67.4	+ 0.3	84	17	74	48	22	61	24		62	60	82	4.37	+ 0.4	9	10,331	n.	44	ne.	10	14	8	9	4.5	.....	.....
Columbia, S. C.	351	41	57	29.72	30.10	+ .03	64.4	+ 0.4	85	9	74	41	22	55	29		56	52	70	1.33	− 1.5	5	6,101	ne.	34	sw.	20	13	9	9	4.5	.....	.....
Augusta	180	62	77	29.89	30.08	+ .01	65.6	+ 2.0	85	16	76	40	22	56	31		58	55	75	1.10	− 1.2	7	4,941	ne.	27	sw.	20	14	6	11	4.6	.....	.....
Savannah	65	150	194	29.99	30.06	+ .01	67.9	+ 1.6	88	17	75	43	22	60	25		62	60	84	4.04	+ 1.4	10	9,469	ne.	46	e.	10	7	9	15	6.3	.....	.....
Jacksonville	43	209	245	29.97	30.02	.00	69.5	− 0.1	86	10	75	43	22	64	22		65	64	88	4.77	− 0.3	20	11,165	n.	38	ne.	27	8	8	15	6.5	.....	.....
Florida Peninsula.							**77.2**	**+ 0.8**											**78**	**3.06**	**− 3.2**									**4.9**		
Key West	22	10	64	29.87	29.89	−0.05	79.3	+ 0.6	88	8	84	69	22	75	14		73	70	77	3.38	− 2.0	12	8,485	ne.	33	nw.	21	13	14	4	4.3	.....	.....
Miami	25	71	79	29.89	29.92	.....	77.2	− 0.6	86	7	82	62	23	72	18		72	70	80	5.03	− 5.5	15	7,472	ne.	32	e.	28	11	13	7	5.2	.....	.....
Sand Key	23	39	72	29.84	29.88	− 0.6	78.8	.....	87	20	81	70	22	76	9		74	72	80	1.36	.....	10	12,722	ne.	43	nw.	21	14	12	5	4.0	.....	.....
Tampa	35	79	96	29.93	29.97	− 0.1	75.0	+ 2.4	89	9	83	49	22	67	27		68	65	77	0.77	− 2.2	7	6,191	ne.	23	ne.	28	6	11	14	6.2	.....	.....
East Gulf States.							**66.6**	**+ 1.0**											**72**	**2.50**	**− 0.3**									**3.2**		
Atlanta	1,174	190	216	28.87	30.11	+0.04	62.3	− 0.1	86	9	71	36	21	53	26		55	50	71	2.11	− 0.2	5	7,471	e.	34	e.	18	18	3	10	3.9	.....	.....
Macon	370	78	87	29.69	30.08	+ .02	65.2	+ 1.5	86	10	75	38	22	55	33		58	53	74	1.72	− 0.4	7	5,352	ne.	31	n.	4	16	5	10	4.1	.....	.....
Thomasville	273	49	58	29.74	30.04	.00	68.9	+ 0.7	88	10	78	39	22	59	34		61	57	74	4.88	+ 1.4	6	4,111	se.	28	se.	18	16	6	9	4.4	.....	.....
Pensacola	56	140	182	29.98	30.04	+ .01	69.6	+ 0.2	85	10	78	42	21	62	27		61	57	70	1.32	− 2.8	7	10,529	ne.	120	se.	18	19	6	6	3.3	.....	.....
Anniston	741	9	57	29.32	30.12	+ .05	63.9	+ 1.5	87	9	76	29	22	52	36		.....	.....	.....	1.38	− 1.0	3	4,172	e.	28	w.	20	21	5	5	2.7	.....	.....
Birmingham	700	11	48	29.34	30.11	+ .04	65.6	+ 1.2	89	8	77	33	22	54	33		55	49	67	0.83	− 1.5	4	4,733	e.	30	se.	18	19	8	4	3.2	.....	.....
Mobile	57	125	161	29.98	30.03	− .01	68.8	+ 1.7	90	9	78	41	22	59	33		61	57	72	2.52	− 0.7	2	7,399	n.	115	e.	18	21	6	4	2.9	.....	.....
Montgomery	223	100	112	29.83	30.08	+ .02	66.2	+ 0.5	90	9	77	38	22	56	30		58	52	66	1.75	− 0.7	4	4,970	ne.	37	e.	18	18	10	3	3.0	.....	.....
Corinth	469	6	....	.....	.....	.....	61.1	.....	90	6	77	29	22	45	49		.....	.....	.....	1.70	.....	6	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Jackson	304	5	....	.....	.....	.....	65.9	.....	94	9	81	31	22	50	48		.....	.....	.....	0.96	.....	6	.....	se.	.....	.....	.....	20	6	5	.....	.....	.....
Meridian	375	85	93	29.67	30.07	+ .01	64.6	+ 1.6	87	15	77	32	22	52	38		57	54	78	0.93	− 1.8	6	3,625	ne.	25	e.	18	21	7	3	2.5	.....	.....
Vicksburg	247	65	74	29.80	30.09	+ .03	66.1	+ 0.8	88	9	77	40	21	55	31		58	54	74	1.55	− 1.2	4	4,446	e.	30	nw.	19	25	3	3	2.0	.....	.....
New Orleans	51	76	84	29.98	30.03	.00	71.6	+ 2.1	87	9	79	50	20	64	25		64	60	76	8.51	+ 5.6	7	5,294	ne.	25	e.	17	22	3	6	2.7	.....	.....
West Gulf States.							**68.0**	**+ 1.3**											**69**	**1.51**	**− 1.3**									**3.0**		
Shreveport	249	77	93	29.80	30.07	+0.02	67.4	+ 1.8	89	13	80	36	20	55	41		57	52	67	2.17	− 1.0	2	4,711	se.	35	w.	19	25	4	2	2.0	.....	.....
Bentonville	1,303	11	44	28.69	30.06	+ .01	59.2	+ 1.2	87	8	71	26	21	47	36		.....	.....	.....	1.45	− 1.4	7	2,094	s.	17	s.	2	20	4	7	3.7	.....	.....
Fort Smith	457	79	94	29.57	30.05	.00	63.6	+ 1.9	90	8	75	32	20	52	35		54	49	68	1.49	− 1.3	7	5,951	e.	33	nw.	19	17	6	8	3.8	.....	.....
Little Rock	357	139	147	29.70	30.08	+ .02	63.3	+ 0.4	87	7	74	35	20	52	32		54	49	66	2.92	+ 0.4	6	5,791	e.	42	w.	19	22	3	6	2.7	.....	.....
Brownsville	57	3	40	.....	.....	.....	74.8	.....	91	3	85	53	20	64	31		.....	.....	.....	2.23	.....	9	.....	e.	.....	.....	.....	.....	.....	.....	.....	.....	.....
Corpus Christi	20	69	77	30.01	30.03	+ .03	73.4	+ 0.8	92	19	79	49	20	68	34		67	64	78	0.06	− 2.0	3	8,491	se.	38	n.	19	14	12	5	4.0	.....	.....
Dallas	512	109	117	29.50	30.04	.....	67.8	.....	90	7	80	34	20	56	33		.....	.....	.....	3.75	.....	4	6,554	se.	39	w.	19	14	10	7	3.8	.....	.....
Fort Worth	670	106	114	29.32	30.02	− .01	68.1	+ 1.8	91	8	80	35	20	57	33		58	51	62	1.89	− 0.6	5	7,496	s.	40	nw.	19	16	8	7	3.9	.....	.....
Galveston	54	106	114	29.99	30.05	+ .02	72.5	+ 0.1	84	5	78	45	20	68	28		66	62	74	0.99	− 3.2	1	7,540	se.	40	n.	19	28	2	1	1.3	.....	.....
Houston	138	111	121	29.90	30.05	.....	71.0	+ 1.1	90	7	82	40	20	60	38		.....	.....	.....	1.05	.....	4	5,369	se.	28	nw.	19	25	5	1	2.0	.....	.....
Palestine	510	64	72	29.51	30.04	+ .01	69.2	+ 3.0	90	13	80	34	20	58	33		58	53	67	0.51	− 3.1	3	4,881	s.	24	nw.	19	21	5	5	2.7	.....	.....
San Antonio	701	119	132	29.31	30.03	+ .02	70.9	+ 1.7	89	13	82	42	20	60	36		61	56	70	2.5	+ 1.1	4	5,175	sw.	34	n.	19	22	7	2	2.5	.....	.....
Taylor	582	55	63	29.46	30.07	+ .05	69.2	+ 0.9	90	13	82	37	20	57	35		.....	.....	.....	1.03	− 1.5	2	5,593	se.	28	n.	19	14	15	2	3.4	.....	.....

TABLE I.—*Climatological data for Weather Bureau Stations, October, 1916*—Continued.

Districts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.				Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.					Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Maximum velocity. Direction.	Maximum velocity. Date.					
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*		°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*							*0–10*	*In.*	*In.*
Ohio Valley and Tennessee.							**57.5**	**+ 0.9**											**70**	**2.20**	**− 0.3**									**3.8**		
Chattanooga	762	180	213	29.31	30.13	+0.04	61.7	+ 0.9	86	7	72	36	21	51	31	53	48	69	4.12	+ 1.3	8	4,629	ne.	36	w.	20	16	8	7	3.8	.....	.....
Knoxville	996	93	100	29.06	30.12	+ .03	59.4	+ 1.3	87	7	71	33	22	48	33	52	48	73	1.97	− 0.6	9	3,136	ne.	23	w.	20	15	9	7	3.8	.....	.....
Memphis	399	76	97	29.69	30.12	+ .05	64.0	+ 1.5	90	7	74	34	21	54	30	54	48	62	2.28	− 0.5	4	5,334	se.	40	w.	19	22	6	3	2.5	.....	.....
Nashville	546	168	191	29.54	30.13	+ .05	60.8	+ 0.5	90	7	73	32	22	48	38	52	46	68	2.67	+ 0.2	5	5,380	ne.	38	sw.	20	18	5	8	3.4	.....	.....
Lexington	989	193	230	29.05	30.13	+ .05	57.6	+ 1.1	88	7	68	33	22	47	32	.....	.....	.....	2.04	− 0.2	6	9,449	se.	46	sw.	20	21	3	7	3.2	T.	.....
Louisville	525	219	255	29.55	30.13	+ .05	58.3	− 0.1	89	7	70	31	22	47	32	50	43	64	2.02	− 0.6	5	7,390	s.	50	sw.	20	19	5	7	3.4	.....	.....
Evansville	431	139	175	29.64	30.11	+ .03	60.0	+ 2.0	91	7	71	35	22	48	33	51	45	65	2.05	− 1.0	8	7,527	s.	48	sw.	20	18	7	6	3.5	.....	.....
Indianapolis	822	194	230	29.22	30.11	+ .04	56.1	+ 1.1	87	7	66	30	22	46	30	47	41	64	1.47	− 1.3	9	8,421	s.	40	nw.	13	16	6	9	4.2	0.4	.....
Terre Haute	575	96	129	29.47	30.09	+ .01	56.4	.....	89	8	68	32	22	45	32	48	41	66	1.53	.....	10	6,858	se.	37	sw.	20	16	8	7	4.4	0.2	.....
Cincinnati	628	11	51	29.44	30.13	+ .05	54.9	+ 1.9	88	6	67	27	22	42	37	48	43	71	1.81	− 0.5	7	4,715	ne.	36	sw.	20	17	6	8	3.6	.....	.....
Columbus	824	173	222	29.25	30.13	+ .05	55.2	+ 1.1	86	8	66	35	21	44	33	47	41	67	1.84	− 0.5	9	7,383	sw.	46	nw.	13	17	6	8	3.8	.....	.....
Dayton	899	181	216	29.14	30.10	.....	54.8	+ 0.7	85	6	66	33	22	43	36	48	44	74	1.42	− 1.0	8	6,750	sw.	44	sw.	20	16	8	7	3.8	T.	.....
Pittsburgh	842	353	410	29.23	30.15	+ .07	54.8	− 0.1	86	8	66	33	23	43	35	47	42	72	2.31	0.0	10	7,311	w.	45	se.	19	16	4	11	4.4	.....	.....
Elkins	1,940	41	50	28.10	30.20	+ .10	51.6	+ 0.2	86	8	68	24	27	36	44	43	40	81	2.32	− 0.1	12	2,519	w.	23	se.	19	17	6	8	4.3	T.	.....
Parkersburg	638	77	84	29.50	30.16	+ .08	55.3	+ 0.7	88	8	69	31	27	42	41	47	44	77	2.53	+ 0.1	8	3,246	se.	28	nw.	25	17	5	9	4.6	.....	.....
Lower Lake Region.							**52.2**	**+ 0.5**											**70**	**2.37**	**−0.9**									**4.9**		
Buffalo	767	247	280	29.26	30.10	+0.05	52.6	+ 1.1	77	4	61	34	18	44	29	46	40	70	2.33	− 1.2	10	13,536	sw.	70	w.	25	12	6	13	5.5	.....	.....
Canton	448	10	61	29.62	30.10	.....	48.2	+ 1.0	79	8	59	24	18	37	36	.....	.....	.....	2.22	− 1.1	10	8,455	sw.	54	w.	17	9	9	13	5.7	T.	.....
Oswego	335	76	91	29.72	30.10	+ .05	51.2	0.0	82	8	60	31	18	42	32	45	40	71	2.16	− 1.2	9	8,291	s.	43	w.	17	9	9	13	5.5	.....	.....
Rochester	523	97	113	29.54	30.12	+ .07	51.9	+ 1.1	84	8	62	22	1	42	34	45	39	67	1.92	− 0.9	10	6,155	sw.	38	w.	16	10	8	13	5.5	.....	.....
Syracuse	597	97	113	29.47	30.12	+ .06	51.9	+ 0.9	83	8	67	32	18	42	39	45	40	69	1.44	− 1.8	7	8,401	s.	50	nw.	17	9	10	12	5.5	.....	.....
Erie	714	130	166	29.32	30.10	+ .05	52.7	+ 0.4	81	8	62	35	23	44	32	46	41	70	2.88	− 0.9	12	11,981	sw.	61	se.	19	10	12	9	4.8	.....	.....
Cleveland	762	190	201	29.28	30.11	+ .05	52.7	+ 0.4	83	8	62	36	21	43	31	46	41	69	2.19	− 0.5	9	10,492	sw.	48	nw.	13	12	11	8	4.4	.....	.....
Sandusky	629	62	103	29.41	30.10	+ .04	53.2	− 0.7	87	8	62	37	21	44	27	46	41	68	1.24	− 1.2	9	9,253	sw.	44	sw.	20	14	9	8	4.2	.....	.....
Toledo	628	208	243	29.42	30.10	+ .05	53.7	+ 1.1	86	8	64	33	20	44	29	46	41	69	2.46	+ 0.2	8	10,630	sw.	60	sw.	20	18	5	8	3.8	T.	.....
Fort Wayne	856	113	124	29.17	30.10	.....	53.0	− 0.7	86	8	64	31	22	42	36	46	41	71	1.66	.....	10	6,773	sw.	46	sw.	20	15	4	12	4.4	0.2	.....
Detroit	730	218	245	29.29	30.09	+ .05	52.9	+ 1.2	85	8	62	34	20	44	30	46	42	73	2.48	+ 0.1	12	9,068	sw.	54	sw.	20	14	7	10	4.7	T.	.....
Upper Lake Region.							**47.6**	**+ 0.1**											**76**	**3.42**	**+ 0.6**									**5.9**		
Alpena	609	13	92	29.37	30.04	+0.01	46.0	+ 0.1	85	5	54	30	24	38	42	42	39	80	3.34	− 0.1	17	9,872	nw.	52	nw.	16	9	10	12	6.0	T.	.....
Escanaba	612	54	60	29.35	30.02	+ .01	44.8	− 0.3	67	7	52	27	24	38	27	41	37	76	3.55	+ 0.5	12	8,801	s.	40	nw.	16	10	5	16	6.1	T.	.....
Grand Haven	632	54	92	29.36	30.05	+ .02	49.2	+ 1.0	76	4	58	33	22	41	31	44	40	75	3.30	+ 0.8	14	9,611	s.	49	w.	25	13	9	9	4.6	.....	.....
Grand Rapids	707	70	87	29.29	30.07	+ .03	51.1	+ 1.0	83	5	60	33	18	42	33	44	40	71	3.73	+ 1.2	14	4,900	s.	32	w.	25	9	9	13	5.7	T.	.....
Houghton	684	62	99	29.25	29.98	+ .02	44.6	− 0.5	83	4	52	26	24	38	34	.....	.....	.....	2.82	− 0.4	16	7,741	e.	42	nw.	25	6	4	21	7.6	7.2	.....
Lansing	878	11	62	29.12	30.07	.....	49.7	+ 1.0	84	8	61	29	28	38	38	43	40	80	2.53	+ 0.3	12	4,800	sw.	30	nw.	16	13	7	11	5.0	0.3	.....
Ludington	637	60	66	29.34	30.04	.....	48.0	.....	74	4	55	32	22	41	25	44	40	77	3.94	.....	16	9,145	s.	44	w.	25	11	8	12	5.1	T.	.....
Marquette	734	77	111	29.22	30.03	+ .02	45.6	− 0.1	80	4	53	27	24	38	31	40	36	77	4.89	+ 1.7	18	9,510	nw.	49	sw.	14	5	3	23	7.8	2.5	.....
Port Huron	638	70	120	29.38	30.08	+ .04	49.9	+ 0.4	85	8	60	32	10	40	29	44	41	77	2.15	− 0.6	11	9,121	sw.	42	sw.	20	11	10	10	4.9	.....	.....
Saginaw	641	48	82	29.36	30.06	.....	50.0	.....	85	8	60	32	28	40	36	44	40	77	2.09	− 0.1	14	7,626	s.	39	nw.	16	9	7	15	5.8	T.	.....
Sault Ste. Marie	614	11	61	29.32	30.03	+ .02	44.0	+ 0.6	79	4	51	28	17	37	33	41	38	85	5.49	+ 2.2	16	7,562	se.	37	nw.	13	5	4	22	7.9	5.9	.....
Chicago	823	140	310	29.18	30.07	+ .03	54.4	+ 1.2	87	5	62	35	26	47	31	47	41	66	3.88	+ 1.3	11	10,208	sw.	41	w.	25	18	6	7	4.0	T.	.....
Green Bay	617	109	144	29.35	30.02	.00	47.6	+ 0.5	80	4	56	27	17	40	29	42	38	76	4.73	+ 2.4	14	9,763	s.	52	nw.	16	10	6	15	6.6	0.3	.....
Milwaukee	681	119	133	29.30	30.05	+ .02	50.1	− 0.1	83	7	58	31	26	43	31	44	40	76	3.68	+ 1.3	13	8,167	sw.	39	nw.	20	14	7	10	4.6	T.	.....
Duluth	1,133	11	47	28.77	30.01	+ .01	42.0	− 3.2	71	14	50	19	17	34	28	37	33	78	1.13	− 1.6	10	9,612	w.	54	nw.	16	9	4	18	6.6	3.4	.....
North Dakota.							**40.5**	**− 2.6**											**74**	**0.47**	**− 0.8**									**5.7**		
Moorhead	940	8	57	29.01	30.04	+0.04	42.0	− 0.8	73	3	53	16	20	31	41	37	34	82	0.41	+ 1.7	5	6,518	nw.	35	n.	16	16	5	10	4.6	T.	.....
Bismarck	1,674	8	57	28.26	30.08	+ .09	41.8	− 2.3	75	6	54	13	20	30	44	35	29	70	0.18	− 0.8	5	7,259	nw.	42	nw.	16	12	7	12	5.4	0.2	.....
Devils Lake	1,482	11	44	28.41	30.02	+ .03	38.4	− 2.1	73	6	48	6	20	28	39	33	29	77	0.67	− 0.6	7	8,293	sw.	42	ne.	2	7	8	16	6.5	3.5	.....
Grand Forks	835	12	89	.....	.....	.....	38.6	.....	70	6	49	9	20	28	38	34	.....	.....	0.64	.....	7	.....	nw.	37	se.	16	12	11	8	.....	1.8	.....
Williston	1,872	41	48	28.02	30.04	+ .06	40.0	− 2.9	72	13	50	20	9	29	38	34	29	69	0.63	− 0.1	4	6,053	w.	36	nw.	16	7	9	15	6.2	0.6	.....
Upper Mississippi Valley.							**53.2**	**+ 0.2**											**72**	**2.27**	**− 0.2**									**4.9**		
Minneapolis	918	10	208	29.01	30.00	.....	46.9	.....	79	3	55	22	21	38	30	.....	.....	.....	1.60	− 1.0	7	9,569	s.	48	nw.	16	8	7	16	6.2	4.3	.....
St. Paul	837	201	236	29.09	30.00	−0.01	46.4	− 1.7	79	3	55	22	21	38	31	.....	.....	.....	1.26	− 1.1	8	10,161	nw.	52	nw.	16	8	15	8	5.2	3.5	.....
La Crosse	714	11	48	29.24	30.03	+ .01	48.6	− 1.3	86	7	58	28	24	39	33	.....	.....	.....	2.69	+ 0.2	9	4,316	s.	28	nw.	16	11	11	9	5.3	.....	.....
Madison	974	70	78	29.00	30.06	+ .03	49.2	+ 0.4	83	7	58	30	26	40	33	43	38	72	2.97	+ 0.6	13	7,886	s.	40	sw.	16	8	11	12	5.7	T.	.....
Wausau	1,247	4	.....	28.67	30.02	.....	45.2	.....	81	7	54	24	24	36	32	.....	.....	.....	2.60	.....	11	.....	nw.	.....	.....	.....	.....	.....	9	12	10	5.6	T.	.....
Charles City	1,015	10	49	28.95	30.04	+ .02	47.8	− 0.4	86	7	58	18	21	37	34	41	38	78	2.08	0.0	12	5,863	s.	28	se.	3	11	10	10	5.4	3.0	.....
Davenport	606	71	79	29.39	30.05	+ .01	53.8	− 1.2	86	7	64	29	21	44	33	46	41	71	3.52	+ 1.1	12	5,668	sw.	28	nw.	25	15	5	11	4.7	.....	.....
Des Moines	861	84	97	29.12	30.03	.00	53.2	+ 0.7	87	4	63	22	21	43	33	45	39	66	2.11	− 0.6	9	6,223	s.	30	sw.	12	15	4	12	5.0	1.3	.....
Dubuque	698	81	96	29.32	30.08	+ .04	51.6	− 0.4	85	7	61	32	11	42	35	44	39	71	3.32	+ 0.6	13	5,113	s.	35	nw.	16	11	9	11	5.3	.....	.....
Keokuk	614	64	78	29.38	30.06	+ .01	55.2	+ 0.7	87	8	66	24	21	45	30	48	44	74	2.75	+ 0.3	8	5,622	s.	28	w.	20	15	6	10	4.3	2.0	.....
Cairo	356	87	93	29.70	30.09	+ .02	60.6	+ 1.5	89	7	72	34	21	50	31	52	47	68	1.29	− 1.3	4	5,482	n.	36	sw.	20	17	9	5	3.4	.....	.....
Peoria	606	11	45	29.41	30.08	+ .03	54.2	+ 2.2	87	7	66	23	11	43	34	47	43	78	2.93	+ 0.4	7	4,935	s.	26	w.	20	14	7	10	4.5	0.3	.....
Springfield, Ill	644	10	91	29.39	30.07	+ .02	55.4	+ 0.8	87	8	66	31	20	45	32	48	43	72	1.97	− 0.6	10	5,952	s.	27	sw.	20	16	4	11	4.5	1.8	.....
Hannibal	534	74	109	29.50	30.08	+ .03	55.8	− 0.1	88	8	67	24	21	44	37	.....	.....	.....	1.59	0.0	9	6,479	sw.	30	w.	25	18	2	11	4.0	1.8	.....
St. Louis	567	265	303	29.46	30.07	+ .01	59.2	+ 0.8	86	7	69	30	21	49	27	51	45	67	1.64	− 0.8	8	9,538	s.	44	w.	30	16	8	7	3.8	0.1	.....
Missouri Valley.							**53.1**	**+4.1**											**66**	**1.52**	**−0.4**									**4.4**		
Columbia, Mo	781	11	84	29.23	30.07	+0.02	58.0	+3.2	89	8	69	25	21	47	33	.....	.....	.....	1.55	−0.9	7	5,684	se.	30	w.	20	14	6	11	4.6	T.	.....
Kansas City	963	161	181	29.01	30.05	+ .01	57.4	+1.6	88	8	67	26	20	48	30	49	43	66	4.17	+2.0	11	8,828	s.	37	nw.	20	16	5	10	4.2	T.	.....
St. Joseph	967	11	49	29.00	30.04	.....	56.1	.....	89	8	67	24	20	46	36	47	41	65	1.78	.....	7	6,255	se.	38	nw.	20	16	6	9	4.3	T.	.....
Springfield, Mo	1,324	98	104	28.68	30.08	+ .03	59.4	+2.1	87	5	70	27	21	48	32	49	42	62	1.24	−1.6	6	8,194	se.	37	nw.	20	17	5	9	4.2	T.	.....
Iola	984	11	50	28.99	30.04	.00	58.9	+2.0	89	8	71	26	21	47	38	.....	.....	.....	1.67	−0.6	8	5,232	s.	25	s.	28	15	8	8	4.1	T.	.....
Topeka	983	85	101	.....	.....	.....	57.4	+1.1	90	8	68	25	20	47	35	.....	.....	.....	3.14	+1.2	8	7,779	s.	37	s.	2	16	7	8	4.2	0.1	.....
Drexel	1,299	10	53	28.64	30.04	.....	52.0	.....	91	3	64	18	20	40	36	43	38	69	1.17	.....	3	8,533	ne.	39	s.	3	16	7	8	4.2	5.0	.....
Lincoln	1,189	11	84	28.76	30.03	.00	54.2	+0.9	92	3	66	18	20	43	36	44	37	61	1.11	−0.7	4	8,912	s.	37	s.	3	15	10	6	4.0	3.1	.....
Omaha	1,105	105	122	28.85	30.04	+ .01	53.8	−0.4	88	7	64	20	20	44	34	45	39	65	1.17	−1.2	6	6,944	s.	34	nw.	19	16	6	9	4.3	4.1	.....
Valentine	2,598	47	54	27.32	30.07	+ .06	46.4	−2.1	81	6	59	11	20	33	44	38	32	68	0.65	−0.7	7	7,341	nw.	40	s.	17	11	13	7	5.0	3.6	.....
Sioux City	1,135	94	164	28.81	30.04	+ .02	49.8	−1.3	89	3	61	17	20	39	38	42	37	68	1.52	−0.3	7	10,029	s.	43	nw.	30	16	5	10	4.6	5.0	.....
Huron	1,306	59	74	28.65	30.07	+ .06	45.0	+0.3	82	3	58	14	20	32	41	37	33	73	0.49	−0.8	5	8,742	nw.	44	nw.	30	10	15	6	5.2	2.8	.....
Pierre	1,572	70	75	28.38	30.07	+ .06	47.8	−1.3	82	17	60	20	20	36	48	39	33	65	0.67	−0.1	5	6,562	nw.	34	w.	26	13	13	5	4.4	0.9	.....
Yankton	1,233	49	57	28.70	30.03	+ .02	49.3	−1.2	92	3	61	17	20	38	42	.....	.....	.....	0.91	−0.7	7	6,214	w.	29	nw.	30	12	11	8	5.0	4.0	.....

TABLE I.—*Climatological data for Weather Bureau Stations, October, 1916*—Continued.

ts and stations.	Elevation of instruments.			Pressure.			Temperature of the air.										Mean wet thermometer.	Mean temperature of the dew point.	Mean relative humidity.	Precipitation.			Wind.					Clear days.	Partly cloudy days.	Cloudy days.	Average cloudiness, tenths.	Total snowfall.	Snow on ground at end of month.
	Barometer above sea level.	Thermometer above ground.	Anemometer above ground.	Station, reduced to mean of 24 hours.	Sea level, reduced to mean of 24 hours.	Departure from normal.	Mean max.+mean min.÷2.	Departure from normal.	Maximum.	Date.	Mean maximum.	Minimum.	Date.	Mean minimum.	Greatest daily range.				Total.	Departure from normal.	Days with 0.01 inch or more.	Total movement.	Prevailing direction.	Maximum velocity. Miles per hour.	Direction.	Date.						
	Ft.	*Ft.*	*Ft.*	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F*		°*F*	°*F.*		°*F*	°*F.*	°*F.*	°*F.*	%	*In.*	*In.*		*Miles.*								*0–10*	*In.*	*In.*
Northern Slope.							**42.1**	**−2.6**										**68**	**1.76**	**+0.5**										**5.2**		
Billings	3,140	5	....	.....	.....	.....	41.8	.....	77	17	54	7	19	29	44	.....	.....	.....	1.72	.....	.....	.....	.....	.....	.....	.....	14	8	9	.....	.....	.....
Havre	2,505	11	44	27.39	30.06	+0.08	39.9	−3.7	74	13	51	4	5	28	40	36	31	75	1.01	+0.5	5	5,782	sw.	36	sw.	29	9	8	14	6.0	8.4	....
Helena	4,110	87	114	25.86	30.12	+ .09	41.2	−2.8	73	16	51	15	19	31	33	34	28	67	2.06	+1.2	7	5,976	sw.	38	sw.	30	10	10	11	5.4	20.5	....
Kalispell	2,962	11	34	27.00	30.11	+ .10	40.5	−2.0	67	16	53	19	19	28	36	34	29	69	0.62	−0.6	8	2,918	w.	23	n.	17	11	9	11	5.4	T.	....
Miles City	2,371	26	48	27.54	30.13	+ .13	45.0	−1.5	78	13	56	26	9	34	42	38	33	73	0.58	−0.2	10	4,174	se.	27	w.	31	13	12	6	4.4	1.7	....
Rapid City	3,250	50	58	26.65	30.12	+ .11	44.4	−2.2	81	17	56	20	20	32	45	36	28	58	0.52	−0.6	9	6,370	n.	37	n.	16	10	10	11	5.7	1.1	....
Cheyenne	6,088	84	101	24.03	30.05	+ .04	42.9	−2.4	73	6	54	12	19	32	42	35	29	65	1.95	+1.2	10	9,205	w.	53	w.	1	13	11	7	4.6	9.6	....
Lander	5,372	60	68	24.68	30.10	+ .06	40.4	−1.7	75	17	55	3	24	26	40	33	26	64	1.96	+0.9	8	3,364	sw.	34	sw.	30	12	9	10	5.4	17.4	....
Sheridan	3,790	10	47	26.16	30.13	.....	39.6	.....	74	13	53	7	24	27	46	33	29	73	2.85	.....	13	3,614	nw.	46	nw.	30	14	3	14	5.6	13.2	....
Yellowstone Park	6,200	11	48	23.91	30.13	+ .11	35.4	−6.1	65	16	46	7	19	25	32	29	24	70	3.47	+2.3	11	5,600	s.	46	nw.	17	10	8	13	5.8	21.8	....
North Platte	2,821	11	51	27.13	30.08	+ .06	49.4	−0.6	90	3	64	14	20	35	49	39	33	66	0.81	−0.3	5	6,511	w.	31	sw.	3	19	3	9	3.7	6.3	....
Middle Slope.							**55.5**	**0.0**										**63**	**1.42**	**−0.1**										**4.0**		
Denver	5,292	106	113	24.76	30.04	+0.03	48.2	−2.8	80	6	60	18	19	36	38	39	30	58	1.92	+1.0	9	5,751	se.	34	nw.	15	16	7	8	4.2	6.	....
Pueblo	4,685	80	86	25.32	30.01	+ .02	51.6	−0.7	83	2	66	20	20	37	52	40	31	56	0.71	0.0	4	4,409	nw.	43	w.	3	18	6	7	3.7	4.9	....
Concordia	1,392	50	58	28.56	30.04	+ .01	56.1	+0.7	91	4	68	21	20	44	37	46	40	64	1.06	−0.9	4	7,164	s.	32	s.	2	13	9	9	4.5	1.8	....
Dodge City	2,509	11	51	27.46	30.07	+ .05	56.2	+1.5	90	2	69	22	20	44	47	46	41	68	0.79	−0.6	6	8,699	s.	37	s.	1	19	7	5	3.4	0.	....
Wichita	1,358	139	158	28.58	30.02	− .01	58.8	0.0	88	4	69	26	20	49	33	50	43	65	2.32	0.0	7	10,330	s.	41	nw.	19	15	8	8	4.5	T	....
Altus	1,410	5	....	.....	.....	.....	63.3	.....	91	5	76	29	20	51	26	.....	.....	.....	4.20	.....	9	.....	nw.	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Muskogee	652	4	....	.....	.....	.....	63.2	.....	94	5	77	29	21	50	40	.....	.....	.....	2.44	.....	8	.....	s.	.....	.....	.....	18	2	11	.....	.....	.....
Oklahoma	1,214	10	47	28.76	30.05	+ .02	62.4	+1.1	91	5	74	28	20	51	39	52	47	68	1.73	−0.1	5	9,842	s.	44	n.	19	19	5	7	3.7		
Southern Slope.							**62.7**	**+0.3**										**64**	**2.24**	**+0.4**										**3.0**		
Abilene	1,738	10	52	28.22	30.02	+0.01	65.8	+1.6	88	8	78	32	20	54	34	55	48	63	3.31	+1.0	3	7,377	s.	34	sw.	22	20	6	5	3.1	.....	....
Amarillo	3,676	10	49	26.31	30.04	+ .04	57.2	+1.1	89	3	70	27	19	45	39	47	42	69	2.90	+1.2	7	8,091	s.	37	nw.	18	19	4	8	3.4	.....	....
Del Rio	944	64	71	29.02	30.00	+ .02	70.2	+0.3	88	31	80	41	21	60	34	.....	.....	.....	0.42	−1.6	3	6,980	e.	36	nw.	19	18	11	2	2.7	.....	....
Roswell	3,566	75	85	26.40	30.00	+ .04	57.6	−1.9	88	2	72	31	20	43	43	47	39	60	2.31	+0.8	7	5,522	s.	32	nw.	28	20	5	6	3.0	.....	....
Southern Plateau.							**57.5**	**−2.3**										**52**	**1.06**	**+0.5**										**2.2**		
El Paso	3,762	110	133	26.20	29.93	+0.01	64.7	+2.3	89	5	77	40	26	52	38	51	40	49	1.07	+0.1	7	8,166	e.	41	nw.	12	23	7	1	1.9	.....	....
Santa Fe	7,013	57	66	23.29	29.97	+ .01	50.8	+0.8	71	3	60	30	25	41	28	40	32	57	2.76	+1.7	10	6,614	se.	36	se.	23	14	12	5	3.7	.....	....
Flagstaff	6,908	8	57	29.36	29.95	+ .03	44.1	−0.6	69	31	57	21	30	32	47	.....	.....	.....	3.61	.....	9	.....	w.	40	sw.	2	18	9	4	2.8	.....	....
Phoenix	1,108	76	81	28.76	29.91	+ .03	66.2	−4.0	89	21	81	41	30	51	43	54	48	60	0.65	+0.3	2	3,304	e.	19	e.	25	24	5	2	2.0	.....	....
Yuma	141	9	54	29.75	29.90	+ .03	68.5	−3.9	95	17	84	46	27	53	40	53	39	42	0.00	−0.2	0	3,782	w.	20	nw.	15	31	0	0	0.2	.....	....
Independence	3,910	11	42	26.00	30.00	+ .05	50.9	−8.4	78	16	66	26	3	35	41	41	30	50	0.84	+0.5	5	3,777	nw.	24	nw.	2	20	4	7	2.6	.....	....
Middle Plateau.							**47.5**	**− 3.3**										**58**	**1.78**	**+ 1.0**										**3.2**		
Reno	4,532	74	81	25.50	30.05	+0.06	46.9	− 2.8	76	21	61	24	24	33	44	37	27	53	1.13	+ 0.7	7	3,837	w.	36	w.	1	20	2	9	3.4	0.4	....
Tonopah	6,090	12	20	24.08	30.00	.....	46.0	.....	69	17	55	24	23	37	27	37	27	52	1.35	+ 0.5	6	5,687	w.	37	nw.	18	16	10	5	3.4	6.0	....
Winnemucca	4,344	18	56	25.66	30.08	+ .03	44.9	− 3.7	74	16	60	18	23	30	46	36	28	62	1.42	+ 0.9	8	4,447	ne.	27	sw.	1	21	4	6	2.8	0.5	....
Modena	5,479	10	43	24.62	29.99	+ .03	45.0	− 5.1	69	21	59	20	25	31	42	36	27	57	2.18	+ 1.4	7	7,904	sw.	42	s.	2	20	7	4	2.7	0.2	....
Salt Lake City	4,360	147	189	25.64	30.02	+ .01	49.8	− 2.4	72	17	60	31	24	40	30	42	34	60	2.45	+ 1.0	8	5,345	nw.	34	se.	6	20	3	8	3.3	T	....
Grand Junction	4,602	82	96	25.40	30.00	+ .01	51.0	− 2.3	75	6	63	29	19	39	34	43	36	62	2.12	+ 1.2	11	5,284	se.	38	sw.	18	18	7	6	3.4	.....	....
Northern Plateau.							**47.9**	**− 1.6**										**55**	**0.66**	**− 0.9**										**3.8**		
Baker	3,471	48	53	26.51	30.13	+0.05	44.0	− 1.5	75	16	58	19	23	30	38	36	27	57	0.21	− 0.7	5	4,998	se.	22	n.	17	19	5	7	3.5	T.	....
Boise	2,739	78	86	27.22	30.10	+ .04	48.7	− 1.8	75	16	60	26	23	37	33	41	33	58	0.84	− 0.4	3	3,269	nw.	25	nw.	27	15	7	9	4.0	.....	....
Lewiston	757	40	48	29.32	30.14	+ .07	48.9	− 2.9	77	13	64	25	23	34	42	.....	.....	.....	0.27	− 0.9	3	1,546	w.	18	w.	31	18	6	7	3.6	.....	....
Pocatello	4,477	60	68	25.50	30.05	+ .01	46.4	− 1.6	69	16	58	22	19	35	35	38	31	62	2.11	− 1.1	10	5,795	se.	35	sw.	18	12	10	9	5.0	0.4	....
Spokane	1,929	101	110	28.04	30.12	+ .06	47.0	− 0.3	75	16	60	25	22	34	39	38	27	50	0.17	− 1.3	2	3,924	sw.	32	sw.	21	13	13	5	4.0	.....	....
Walla Walla	991	57	65	29.03	30.10	+ .03	52.4	− 1.3	80	16	64	32	8	41	31	43	32	48	0.38	− 1.1	3	3,067	s.	21	w.	30	21	4	6	3.0	.....	....
North Pacific Coast Region.							**50.0**	**− 1.7**										**78**	**1.81**	**− 2.2**										**5.1**		
North Head	211	11	56	29.90	30.14	+0.09	50.0	− 2.9	65	10	54	43	18	46	19	48	46	87	1.77	− 2.1	7	8,328	n.	72	s.	29	13	5	13	5.5	.....	....
Seattle	125	215	250	30.03	30.16	+ .11	49.1	− 1.7	69	9	56	34	4	42	28	46	42	78	1.18	− 1.7	9	5,661	n.	51	s.	29	9	9	13	6.0	.....	....
Tacoma	213	113	120	29.93	30.16	+ .12	48.6	− 2.0	68	9	57	32	3	41	27	45	41	78	1.95	− 1.4	8	3,847	n.	28	sw.	30	9	11	11	6.0	.....	....
Tatoosh Island	109	7	57	30.03	30.13	+ .12	48.3	− 1.6	64	7	52	41	29	44	16	46	44	88	4.30	− 3.7	12	8,946	ne.	76	s.	28	11	7	13	5.5	.....	....
Medford	1,425	4	....	.....	.....	.....	51.0	.....	84	16	69	25	4	33	48	.....	.....	.....	0.28	.....	6	.....	e.	.....	.....	.....	19	4	8	.....	.....	.....
North Yakima	1,076	4	....	.....	.....	.....	50.4	.....	78	16	66	24	23	35	42	.....	.....	.....	0.05	.....	1	.....	nw.	.....	.....	.....	23	5	3	.....	.....	.....
Portland, Oreg	153	68	106	29.96	30.12	+ .06	53.2	− 0.1	73	10	63	34	4	43	29	47	41	67	1.26	− 2.4	4	4,123	nw.	30	ne.	8	11	12	8	5.0	.....	....
Roseburg	510	9	57	29.56	30.12	+ .04	50.9	− 1.9	76	13	65	29	23	36	42	44	38	68	0.43	− 2.2	5	1,591	nw.	18	se.	30	19	10	2	2.7	.....	....
Middle Pacific Coast Region.							**55.1**	**− 3.6**										**71**	**1.01**	**− 0.6**										**4.7**		
Eureka	62	73	89	30.01	30.08	+0.02	50.2	− 2.9	65	5	56	38	5	45	27	48	46	86	0.47	− 2.2	5	3,321	se.	30	n.	5	8	7	16	6.5	.....	....
Mount Tamalpais	2,375	11	18	27.57	30.04	+ .03	53.4	− 5.3	70	26	59	38	4	48	20	46	39	63	0.85	− 1.1	9	10,566	nw.	57	nw.	2	20	4	7	3.0	.....	....
Point Reyes Light	490	7	18	29.49	30.01	.....	52.1	− 2.6	66	25	56	45	4	49	20	.....	.....	.....	0.33	.....	5	12,030	nw.	56	nw.	27	7	5	19	7.0	.....	....
Red Bluff	332	50	56	29.65	30.01	− .02	59.4	− 4.4	83	13	71	38	29	48	36	50	41	57	2.60	+ 1.0	5	2,859	se.	18	s.	1	22	5	4	2.3	.....	....
Sacramento	69	106	117	29.95	30.02	+ .03	58.2	− 4.0	79	16	70	37	29	46	34	51	45	68	0.79	− 0.2	5	4,499	s.	27	sw.	1	20	8	3	3.1	.....	....
San Francisco	155	209	213	29.87	30.04	+ .03	56.9	− 1.5	77	25	63	46	29	51	26	52	49	82	0.52	− 0.8	7	5,101	sw.	25	sw.	13	7	11	13	5.9	.....	....
San Jose	141	12	110	29.90	30.05	.....	55.8	− 4.5	78	25	65	35	29	46	40	.....	.....	.....	0.84	− 0.1	8	3,264	nw.	24	nw.	29	10	9	12	5.3	.....	....
South Pacific Coast Region.							**59.0**	**− 3.2**										**76**	**1.64**	**+ 0.8**										**4.1**		
Fresno	327	89	98	29.66	30.02	+0.06	59.8	− 4.9	80	21	71	39	29	48	33	52	47	67	1.16	+ 0.4	6	3,411	nw.	19	nw.	28	18	7	6	3.0	.....	....
Los Angeles	338	159	191	29.64	30.01	+ .06	59.7	− 2.6	90	25	67	44	31	52	32	53	49	78	2.71	+ 1.9	6	3,744	sw.	27	s.	2	9	14	8	5.0	.....	....
San Diego	87	62	70	29.90	29.99	+ .04	59.3	− 3.7	78	26	65	46	31	54	25	55	53	83	0.87	+ 0.4	6	4,286	nw.	26	s.	6	17	10	4	3.7	.....	....
San Luis Obispo	201	32	40	29.83	30.05	+ .06	57.4	− 1.8	88	25	66	40	5	48	36	51	47	78	1.82	+ 0.5	6	2,863	nw.	24	ne.	31	14	8	9	4.6	.....	....
West Indies.																																
San Juan, P. R	82	8	54	29.79	29.87	−0.03	79.2	.....	90	28	84	71	21	74	16	.....	.....	.....	9.62	+ 3.5	24	6,934	se.	52	n.	9	5	14	12	6.2	.....	....
Panama Canal.																																
Balboa Heights	118	7	97	29.74	29.86	.....	78.0	.....	86	18	83	71	22	73	13	74	73	91	10.17	− 0.3	23	6,283	s.	33	s.	10	0	2	29	8.7	.....	....
Colon	25	5	71	29.82	29.85	.....	80.3	.....	89	3	86	73	21	74	15	75	74	89	17.59	+ 2.8	23	5,831	se.	33	w.	10	3	6	22	7.8	.....	....

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during October, 1916, at all stations furnished with self-registering gages.*

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Abilene, Tex	15	7:00 a. m.	10:30 a. m.	1.09	7:28 a. m.	7:51 a. m.	0.01	0.11	0.22	0.44	0.58	0.67	.....	.....	.....	.....	.....	.....	.....	.....	.....
Albany, N. Y	19			1.01														0.40			
Alpena, Mich	12			0.59														0.37			
Amarillo, Tex	12			0.82														0.44			
Anniston, Ala	17			0.60														0.52			
Asheville, N. C	16			1.08														0.35			
Atlanta, Ga	29			1.11														0.39			
Atlantic City, N. J	19			0.92														0.29			
Augusta, Ga	18			0.74														0.30			
Baker, Oreg	7			0.08														0.05			
Baltimore, Md	19			1.29														0.32			
Bentonville, Ark	15			0.97														0.24			
Binghamton, N. Y	20	5:43 p. m.	8:30 p. m.	0.71	6:48 p. m.	7:08 p. m.	0.02	0.28	0.30	0.49	0.57	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
Birmingham, Ala	18			0.73														0.25			
Bismarck, N. Dak	3			0.11														0.10			
Block Island, R. I	19			1.11														0.31			
Boise, Idaho	1			0.37														0.25			
Boston, Mass	19			0.56														0.17			
Buffalo, N. Y	19			1.14														0.24			
Burlington, Vt	20			0.30														0.20			
Cairo, Ill	18			0.88														0.35			
Canton, N. Y	20			0.59														0.41			
Charles City, Iowa	12			0.31														0.29			
Charleston, S. C	19	D. N. a. m	9:50 a. m.	1.31	7:46 a. m.	8:46 a. m	0.16	0.09	0.21	0.32	0.40	0.49	0.59	0.63	0.70	0.80	0.95	1.13	.....	.....	.....
Charlotte, N. C	9	5:15 p. m.	6:20 p. m.	1.24	5:19 p. m.	5:49 p. m.	0.02	0.33	0.64	0.80	0.84	1.00	1.17	.....	.....	.....	.....	.....	.....	.....	.....
Chattanooga, Tenn	19			0.55														0.50			
Cheyenne, Wyo	22–23			0.82														*			
Chicago, Ill	20			1.65														0.48			
Cincinnati, Ohio	18–19			0.93														0.39			
Cleveland, Ohio	19			0.99														0.37			
Columbia, Mo	24			0.33														0.22			
Columbia, S. C	18			0.77														0.28			
Columbus, Ohio	20			0.62														0.56			
Concord, N. H	19–20			1.20														*			
Concordia, Kans	24			0.49														*			
Corpus Christi, Tex	10			0.01														0.01			
Dallas, Tex	13	12:57 p. m.	3:25 p. m.	2.01	1:59 p. m.	2:57 p. m.	0.06	0.19	0.25	0.33	0.41	0.61	0.82	1.11	1.36	1.66	1.81	1.93	.....	.....	.....
Do	13	3:59 p. m.	5:05 p. m.	0.69	4:14 p. m.	4:44 p. m.	0.03	0.14	0.30	0.37	0.43	0.55	0.64	.....	.....	.....	.....	.....	.....	.....	.....
Davenport, Iowa	12			0.61														0.30			
Dayton, Ohio	19			0.43														0.27			
Del Rio, Tex	10			0.32														0.21			
Denver, Colo	14–15			1.24														*			
Des Moines, Iowa	28			0.76														0.16			
Detroit, Mich	19			0.90														0.26			
Devils Lake, N. Dak	16			0.13														0.06			
Dodge City, Kans	24			0.42														0.16			
Dubuque, Iowa	24			1.00														0.21			
Duluth, Minn	19			0.40														*			
Eastport, Me	20			1.20														0.49			
Elkins, W. Va	9			0.78														0.33			
El Paso, Tex	12			0.33														0.2			
Erie, Pa	20			0.26														0.23			
Escanaba, Mich	31			0.59														0.25			
Eureka, Cal	31			0.21														0.11			
Evansville, Ind	18			0.87														0.17			
Flagstaff, Ariz	5–6			1.29														*			
Fort Smith, Ark	16			0.30														0.22			
Fort Wayne, Ind	18			0.33														0.15			
Fort Worth, Tex	15			0.60														0.56			
Fresno, Cal	4			0.45														0.16			
Galveston, Tex	17			0.99														*			
Grand Haven, Mich	20			0.87														0.31			
Grand Junction, Colo	7			0.51														0.21			
Grand Rapids, Mich	20			1.11														0.41			
Green Bay, Wis	31			0.51														0.25			
Hannibal, Mo	24			0.89														0.25			
Harrisburg, Pa	19			1.21														0.34			
Hartford, Conn	19			0.88														0.22			
Hatteras, N. C	20			1.95														0.45			
Havre, Mont	2–3			0.80														*			
Helena, Mont	2–3			0.76														*			
Houghton, Mich	16			0.81														*			
Houston, Tex	10	3:45 p. m.	8:15 p. m.	0.90	4:02 p. m.	4:23 p. m.	0.06	0.08	0.23	0.42	0.58	0.63	.....	.....	.....	.....	.....	.....	.....	.....	.....
Huron, S. Dak	18–19			0.26														*			
Independence, Cal	6			0.40														0.16			
Indianapolis, Ind	20			0.54														0.38			
Iola, Kans	19			0.35														0.20			
Jacksonville, Fla	6			2.73														0.66			
Kalispell, Mont	27			0.21														*			
Kansas City, Mo	24	D. N. a. m.	11:05 a. m.	2.22	7:27 a. m.	8:16 a. m.	0.58	0.06	0.11	0.20	0.26	0.32	0.47	0.57	0.60	0.67	0.75	.....	.....	.....	.....
Keokuk, Iowa	23–24			1.34														*			
Key West, Fla	1	10:35 a. m.	12:35 p. m.	1.25	11:37 a. m.	12:11 p. m.	0.11	0.08	0.13	0.28	0.52	0.86	1.08	1.14	.....	.....	.....	.....	.....	.....	.....
Knoxville, Tenn	20			0.19														0.19			
La Crosse, Wis	12			0.62														0.36			
Lander, Wyo	22–23			0.76														*			
Lansing, Mich	19			0.72														0.18			
Lewiston, Idaho	27			0.19														0.06			
Lexington, Ky	20			0.45														0.36			
Lincoln, Nebr	19			0.50														*			
	23–24			0.50														*			
Little Rock, Ark	18			2.53														0.29			
Los Angeles, Cal	5–6			0.83														0.29			
Louisville, Ky	20			0.38														0.31			
Ludington, Mich	12			0.70														0.22			
Lynchburg, Va	19			1.06														0.24			
Macon, Ga	18			0.77														0.35			
Madison, Wis	20			1.02														0.15			
Marquette, Mich	12			0.61														0.23			

* Self-register not in use. † Partly estimated. ‡ No precipitation occurred during month.

TABLE II.—*Accumulated amounts of precipitation for each 5 minutes, for the principal storms in which the rate of fall equaled or exceeded 0.25 inch in any 5 minutes, or 0.80 in 1 hour, during October, 1916, at all stations furnished with self-registering gages*—Continued.

Stations.	Date.	Total duration.		Total amount of precipitation.	Excessive rate.		Amount before excessive rate began.	Depths of precipitation (in inches) during periods of time indicated.													
		From—	To—		Began—	Ended—		5 min.	10 min.	15 min.	20 min.	25 min.	30 min.	35 min.	40 min.	45 min.	50 min.	60 min.	80 min.	100 min.	120 min.
Memphis, Tenn	19			0.31														0.28			
Meridian, Miss	9			0.33														0.20			
Miami, Fla	5	D.N.a.m.	9:38 a.m.	1.42	8:11 a.m.	9:00 a.m.	0.35	0.18	0.23	0.33	0.39	0.43	0.53	0.67	0.81	0.94	1.06	.....			
	24	9:00 p.m.	9:45 p.m.	0.62	9:00 p.m.	9:13 p.m.	0.00	0.24	0.53	0.61											
Milwaukee, Wis	20			1.74														*			
Minneapolis, Minn	12			0.25														0.24			
Mobile, Ala	17–18	D.N.a.m.	D.N.a.m.	2.00	3:42 a.m.	4:12 a.m.	0.04	0.21	0.45	0.76	1.03	1.21	1.27								
Modena, Utah	[1]30–1			0.88														0.30			
Montgomery, Ala	18			1.61														0.67			
Moorhead, Minn	7			0.24														0.08			
Mount Tamaplais, Cal	4			0.19														0.19			
Nantucket, Mass	19			0.50														0.19			
Nashville, Tenn	18			1.81														0.25			
New Haven, Conn	19			1.66														0.45			
New Orleans, La	8	1:35 p.m.	4:00 p.m.	1.85	1:50 p.m.	2:09 p.m.	0.07	0.18	0.49	0.83	1.12										
	16	11:55 a.m.	[2]6:45 a.m.	5.67	8:24 p.m.	8:54 p.m.	1.04	0.24	0.54	0.66	0.84	0.98	1.03								
New York, N.Y	19			0.44														0.17			
Norfolk, Va	9–10	9:45 p.m.	D.N.a.m.	0.64	10:20 p.m.	10:39 p.m.	0.14	0.15	0.32	0.37	0.43										
Northfield, Vt	20–21			0.58														0.25			
North Head, Wash	29			0.48														0.91			
North Platte, Nebr	23–24			0.47														*			
Oklahoma, Okla	15			0.75														0.41			
Omaha, Nebr	19			0.50														*			
Oswego, N.Y	20	5:57 p.m.	8:15 p.m.	0.71	6:08 p.m.	6:28 p.m.	0.01	0.10	0.28	0.48	0.51										
Palestine, Tex	18			0.38														0.17			
Parkersburg, W.Va	19			1.03														0.25			
Pensacola, Fla	18			1.19														*			
Peoria, Ill	20			1.15														0.22			
Philadelphia, Pa	19			1.00														0.22			
Phoenix, Ariz	5			0.60														0.22			
Pierre, S. Dak	7			0.22														0.17			
Pittsburgh, Pa	19			1.56														0.38			
Pocatello, Idaho	11			0.80														0.19			
Point Reyes Light, Cal	3			0.10														0.08			
Port Huron, Mich	13			0.52														0.18			
Portland, Me	19			0.87														0.41			
Portland, Oreg	27			0.43														0.19			
Providence, R.I	19–20			1.88														0.56			
Pueblo, Colo	15			0.02														0.01			
Raleigh, N.C	19			0.95														0.51			
Rapid City, S. Dak	21			0.11														0.09			
Reading, Pa	19			0.90														0.21			
Red Bluff, Cal	3			0.70														0.39			
Reno, Nev	6			0.40														*			
Richmond, Va	19			0.95														0.25			
Rochester, N.Y	20			0.22														0.21			
Roseburg, Oreg	30			0.18														0.10			
Roswell, N. Mex	12	2:57 p.m.	5:25 p.m.	0.74	3:22 p.m.	3:41 p.m.	0.03	0.12	0.39	0.59	0.62										
Sacramento, Cal	6			0.36														0.18			
Saginaw, Mich	19			0.86														0.28			
St. Joseph, Mo	24			6.87														0.29			
St. Louis, Mo	30	6:44 p.m.	8:10 p.m.	0.68	6:44 p.m.	6:58 p.m.	0.00	0.42	0.55	0.60											
St. Paul, Minn	12			0.26														0.21			
Salt Lake City, Utah	2			0.81														0.34			
San Antonio, Tex	16			2.13														0.50			
San Diego, Cal	23			0.18														0.18			
Sand Key, Fla	6	10:50 a.m.	11:25 a.m.	0.37	11:05 a.m.	11:18 a.m.	0.01	0.07	0.27	0.35											
Sandusky, Ohio	19			0.42														0.17			
San Francisco, Cal	4			0.09														0.08			
San Jose, Cal	4			0.41														0.24			
San Luis Obispo, Cal	9			0.57														0.17			
Santa Fe, N. Mex	14			0.55														0.23			
Sault Ste. Marie, Mich	25–26			1.30														*			
Savannah, Ga	18			1.27														0.62			
Scranton, Pa	20			0.48														0.47			
Seattle, Wash	28–29			0.45														0.11			
Sheridan, Wyo	21–22			1.12														*			
Shreveport, La	17–18			2.16														0.40			
Sioux City, Iowa	19			0.72														*			
Spokane, Wash	29			0.15														0.06			
Springfield, Ill	19–20			0.70														*			
Springfield, Mo	15			0.70														0.42			
Syracuse, N.Y	20			0.56														0.50			
Tacoma, Wash	29			0.69														0.21			
Tampa, Fla	6			0.34														0.29			
Tatoosh Island, Wash	28			1.49														0.29			
Taylor, Tex	16			0.77														0.45			
Terre Haute, Ind	20			0.60														0.44			
Thomasville, Ga	18	8:20 a.m.	4:32 p.m.	4.22	12:26 p.m.	1:16 p.m.	0.55	0.07	0.14	0.20	0.28	0.33	0.38	0.43	0.49	0.64	0.78	.....			
					1:16 p.m.	2:06 p.m.	.....	0.86	0.91	0.95	0.97	1.07	1.16	1.27	1.41	1.62	1.77	.....			
					2:06 p.m.	2:50 p.m.	.....	1.89	2.13	2.34	2.52	2.60	2.76	2.83	2.88	2.93	.....	.....			
					3:43 p.m.	4:09 p.m.	3.60	0.13	0.24	0.26	0.43	0.56	0.59	.....	.....	.....	.....	.....			
Toledo, Ohio	20			0.81														0.48			
Tonopah, Nev	2			0.98														*			
Topeka, Kans	24			1.65														0.34			
Valentine, Nebr	18–19			0.30														*			
Vicksburg, Miss	18			0.95														0.25			
Walla Walla, Wash	27			0.34														0.11			
Washington, D.C	19			1.24														0.33			
Wichita, Kans	15–16	8:40 p.m.	D.N.a.m.	1.16	8:48 p.m.	9:11 p.m.	0.01	0.09	0.27	0.67	1.02	1.12	.....	.....	.....	.....	.....	.....			
Williston, N. Dak	3			0.50														*			
Wilmington, N.C	19	9:40 a.m.	2:20 p.m.	1.74	11:20 a.m.	Noon.....	0.12	0.16	0.25	0.32	0.50	0.71	0.85	1.08	1.23	.....	.....	.....			
Winnemucca, Nev	6			0.19														0.11			
Wytheville, Va	16			0.54														0.28			
Yankton, S. Dak	18–19			0.48														*			
Yellowstone Park, Wyo	17–18			0.93														*			

[1] Sept. 30. [2] Oct. 18. * Self-register not in use. † Record partly estimated. ‡ No precipitation occurred during month.

TABLE III.—*Data furnished by the Canadian Meteorological Service, October, 1916.*

Stations.	Altitude above M. S. L.* Jan. 1, 1916.	Pressure in inches.			Temperature.						Precipitation.		
		Station reduced to mean of 24 hours.	Sea level reduced to mean of 24 hours.	Departure from normal.	Mean max.+ mean min.÷2.	Departure from normal.	Mean maximum.	Mean minimum.	Highest.	Lowest.	Total.	Departure from normal.	Total snowfall.
	Feet.	*Inches.*	*Inches.*	*Inches.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*Inches.*	*Inches.*	*Inches.*
St. Johns, N. F.	125	29.81	29.95	+0.04	46.5	+1.1	52.9	40.1	70	28	4.14	−1.21	.....
Sydney, C. B. I.	48	30.03	*30.07*	+ .11	50.2	+3.7	59.0	41.3	79	30	4.16	−0.53	.....
Halifax, N. S.	88	29.98	*30.09*	+ .09	49.9	+2.7	59.6	40.3	78	25	4.72	−0.83	.....
Yarmouth, N. S.	65	30.02	30.09	+ .07	48.3	+0.7	56.5	40.0	67	27	3.18	−1.52	.....
Charlottetown, P. E. I.	38	30.01	30.05	+ .09	48.6	+2.1	55.7	41.5	73	30	3.55	−1.35	.....
Chatham, N. B.	28	30.03	*30.05*	+ .09	46.2	+3.2	56.0	36.4	82	26	4.07	+0.21	.....
Father Point, Que.	20	30.01	30.05	+ .08	40.6	+0.8	46.9	34.2	63	23	3.23	+0.33	7.6
Quebec, Que.	296	29.75	30.08	+ .08	43.5	+1.1	50.9	36.1	71	25	5.57	+2.42	1.0
Montreal, Que.	187	29.86	30.07	+ .06	47.1	+2.3	54.9	39.3	74	28	3.84	+0.71	0.2
Stonecliffe, Ont.	489	29.44	*30.06*	+ .05	43.2	+0.4	52.9	33.6	83	27	2.85	+0.42	2.2
Ottawa, Ont.	236	29.81	*30.08*	+ .07	45.9	+2.1	55.8	35.9	78	26	2.88	+0.33	T.
Kingston, Ont.	285	29.78	30.09	+ .06	50.5	+3.5	58.8	42.1	75	28	2.67	−0.06	.....
Toronto, Ont.	379	29.67	*30.05*	+ .01	49.5	+2.9	59.6	39.5	85	30	3.91	+1.55	.....
White River, Ont.	1,244	28.64	*29.98*	.00	34.9	−2.2	44.3	25.6	72	11	1.33	−1.02	12.0
Port Stanley, Ont.	592	29.46	30.10	+ .05	47.8	0.0	57.8	37.9	69	27	3.81	+0.83	.....
Southampton, Ont.	656	29.34	.....	.....	48.1	+2.0	57.4	38.9	80	30	4.09	+0.92	.....
Parry Sound, Ont.	688	29.35	30.05	+ .04	46.1	+2.2	54.9	37.4	76	27	5.73	+1.81	0.4
Port Arthur, Ont.	644	29.27	29.98	.00	41.5	+1.6	49.0	34.0	69	20	2.40	−0.16	3.3
Winnipeg, Man.	760	29.17	30.02	+ .04	37.1	−2.0	45.1	29.2	65	14	2.32	+0.62	9.7
Minnedosa, Man.	1,690	28.16	30.02	+ .05	35.3	−2.5	43.5	27.2	64	4	3.00	+1.80	15.4
Qu'Appelle, Sask.	2,115	27.68	29.97	.00	35.6	−3.8	44.1	27.0	72	12	2.78	+1.68	25.5
Medicine Hat, Alberta.	2,144	27.68	*29.98*	+ .01	43.0	−1.8	53.7	32.3	78	21	0.57	−0.01	5.4
Swift Current, Sask.	2,392	27.38	*29.99*	+ .02	38.6	−3.5	49.5	27.7	75	12	1.11	+0.23	8.7
Calgary, Alberta.	3,428	26.43	*30.00*	+ .05	41.5	+1.4	53.3	29.7	74	18	1.20	+0.72	11.4
Banff, Alberta.	4,521	25.40	*30.02*	+ .07	37.8	−1.5	47.0	28.5	64	14	1.24	+0.22	6.9
Edmonton, Alberta.	2,150	27.63	*29.93*	.00	41.0	−0.1	51.1	31.0	72	20	0.34	−0.36	0.9
Prince Albert, Sask.	1,450	28.38	*29.96*	− .01	35.9	−1.2	45.2	26.5	64	11	1.88	+1.05	4.2
Battleford, Sask.	1,592	28.19	*29.95*	− .02	40.1	+0.5	50.5	29.6	71	21	0.71	+0.26	2.7
Kamloops, B. C.	1,262	28.85	30.17	+ .21	45.3	−1.7	56.1	34.4	72	24	0.06	−0.55	T.
Victoria, B. C.	230	29.88	30.14	+ .13	49.2	0.0	55.4	43.0	67	38	1.56	−0.81	.....
Barkerville, B. C.	4,180	25.75	30.11	+ .17	35.2	−4.5	43.2	27.2	46	4	1.00	−1.70	2.2
Hamilton, Bermuda.	151	29.95	30.11	+ .09	74.1	+1.1	78.8	69.4	82	64	3.08	−3.63	.....

* The altitudes given above were furnished by the Director of the Canadian Meteorological Service, Mar. 9, 1916, and refer to cisterns of barometers at the respective stations. Where sea-level pressures and departures are *italicized* new reduction factors are in course of computation.—C. A., Jr.

Chart I. Hydrographs of Several Principal Rivers, October, 1916.

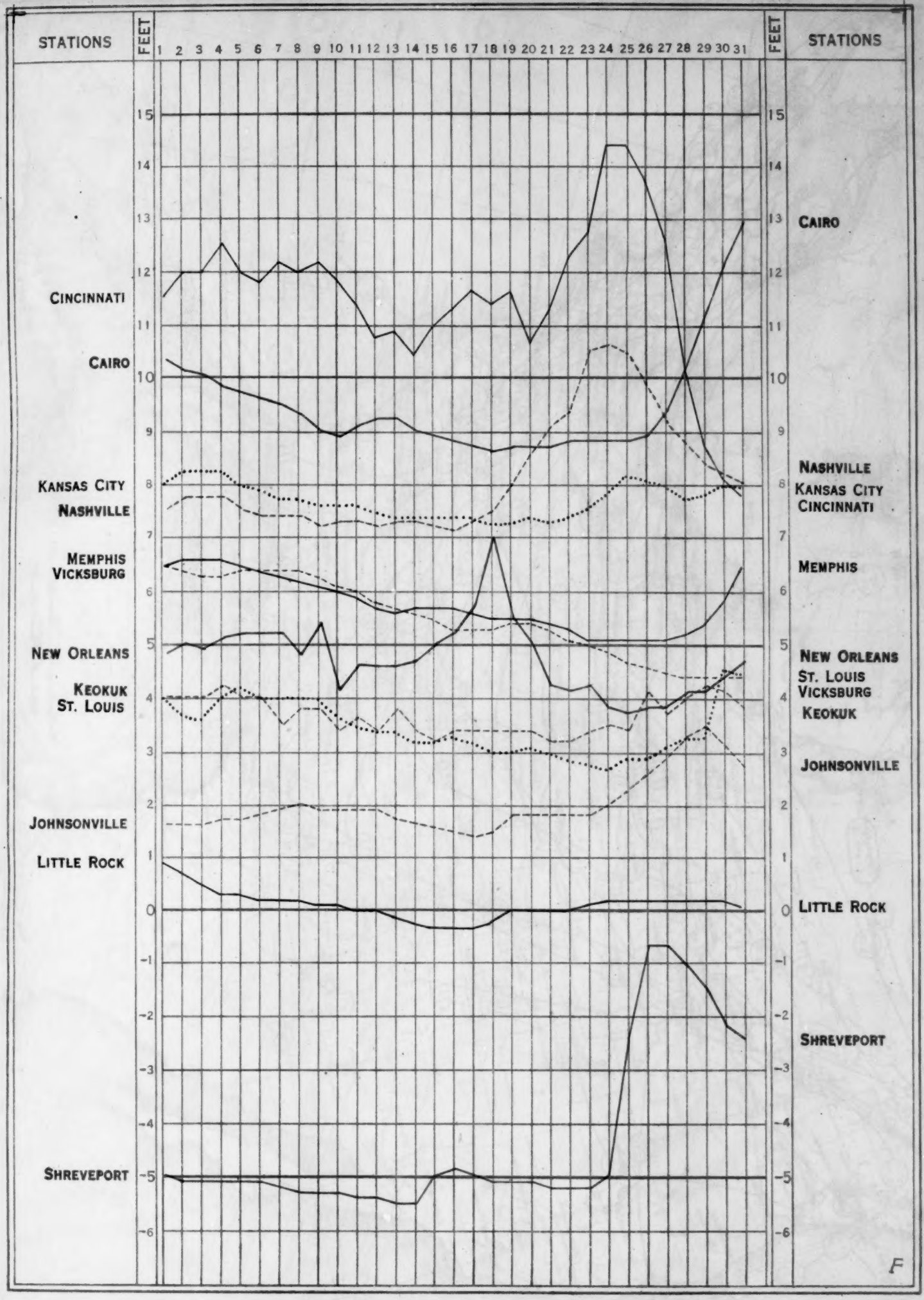


Chart II. Tracks of Centers of High Areas, October, 1916.

(Plotted by H. C. Frankenfield.)

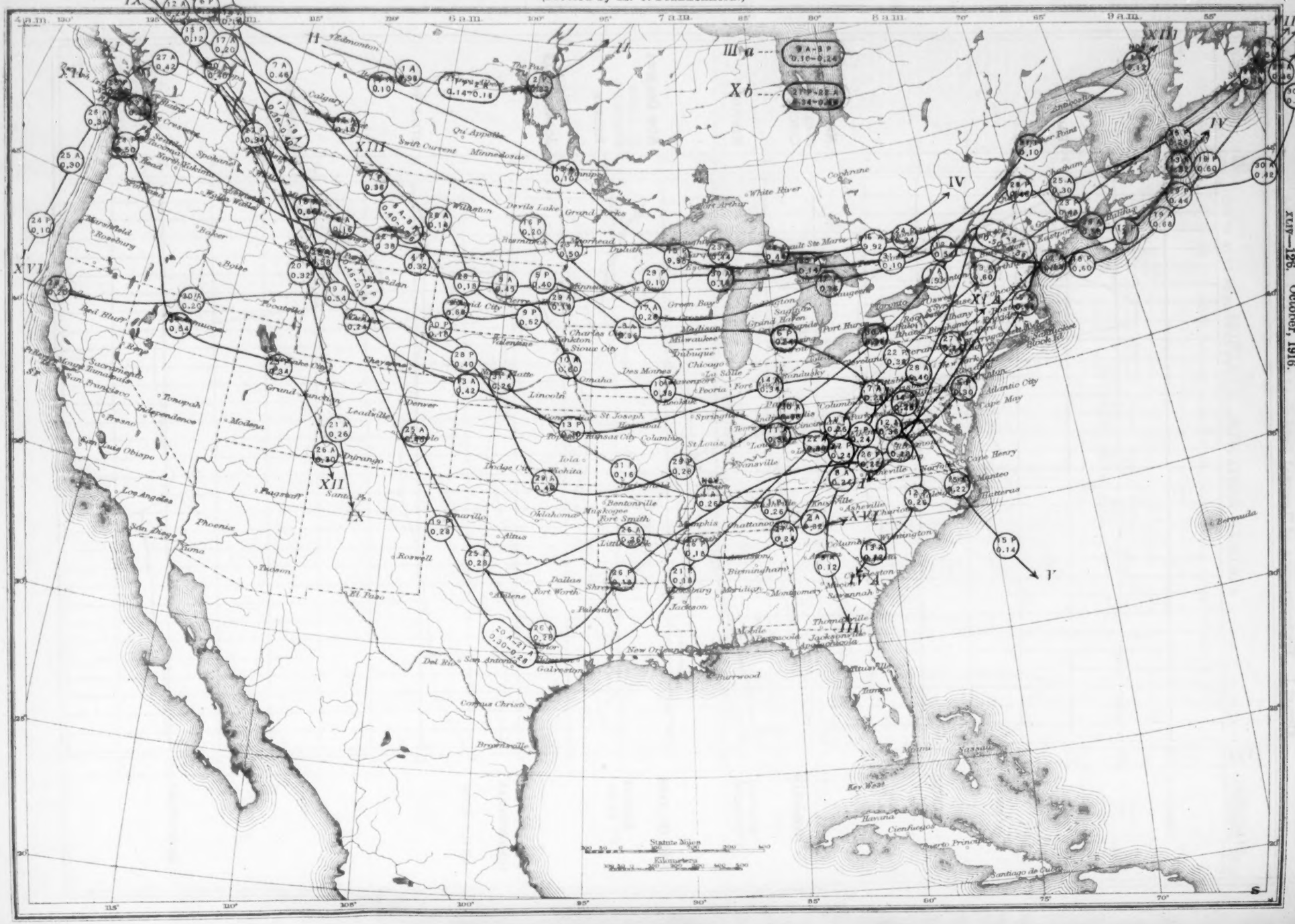


Chart III. Tracks of Centers of Low Areas, October, 1916.

Chart III. Tracks of Centers of Low Areas, October, 1916.

(Plotted by H. C. Frankenfield.)

Chart IV. Departure (°F.) of the Mean Temperature from the Normal, October, 1916.

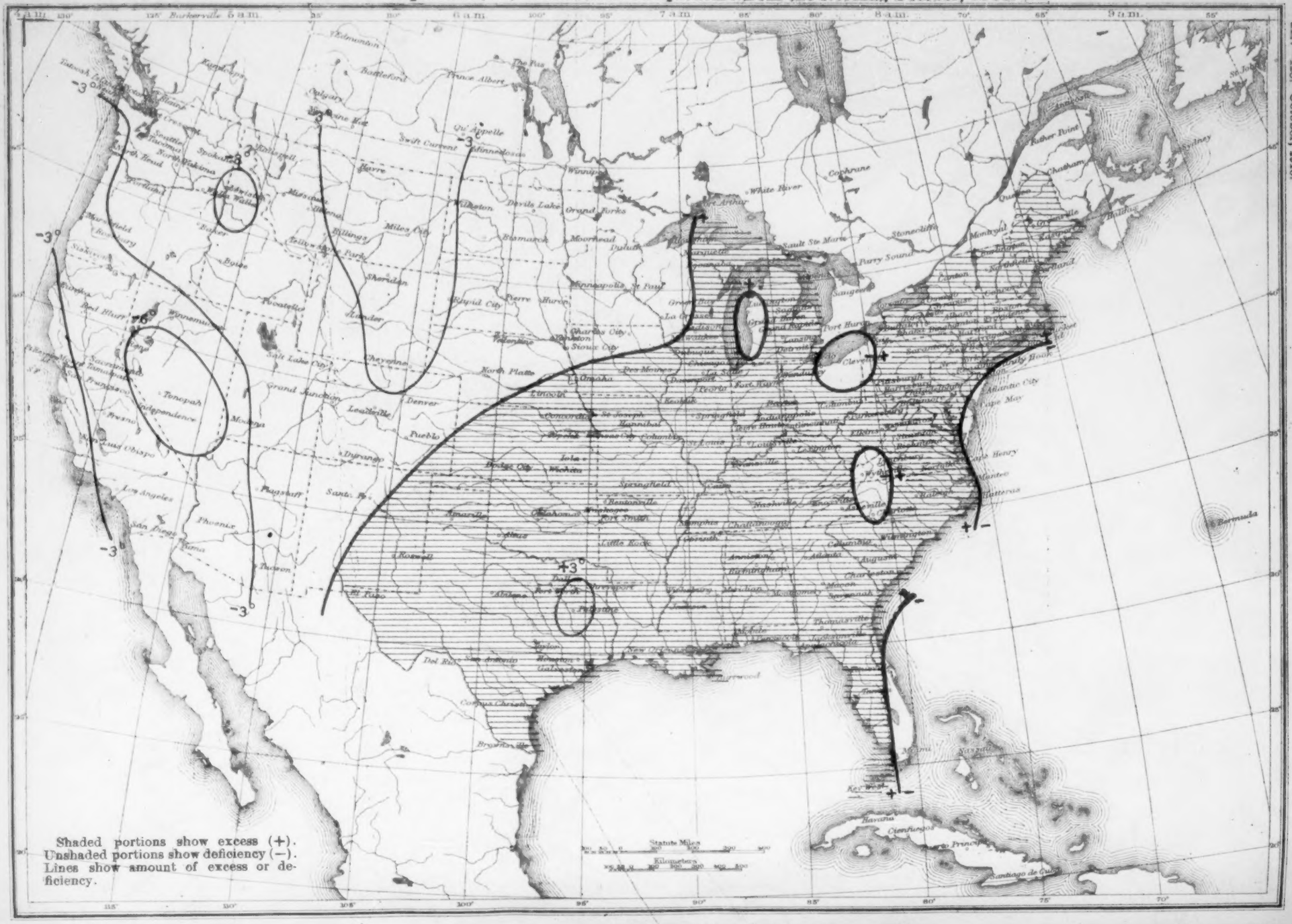

Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.
Statute Miles
Kilometers

Chart V. Total Precipitation, October, 1916.

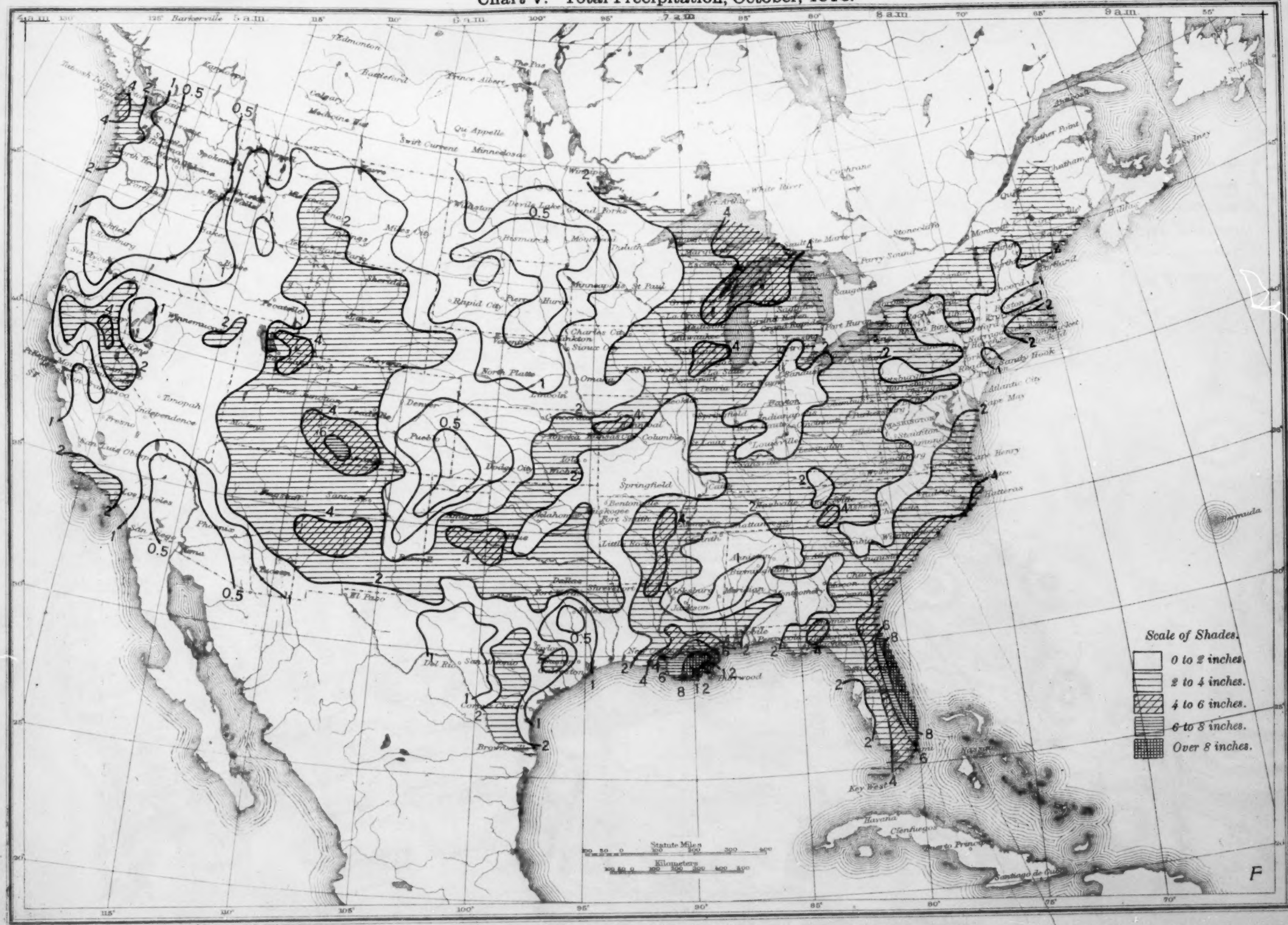


Chart VI. Percentage of Clear Sky between Sunrise and Sunset, October, 1916.

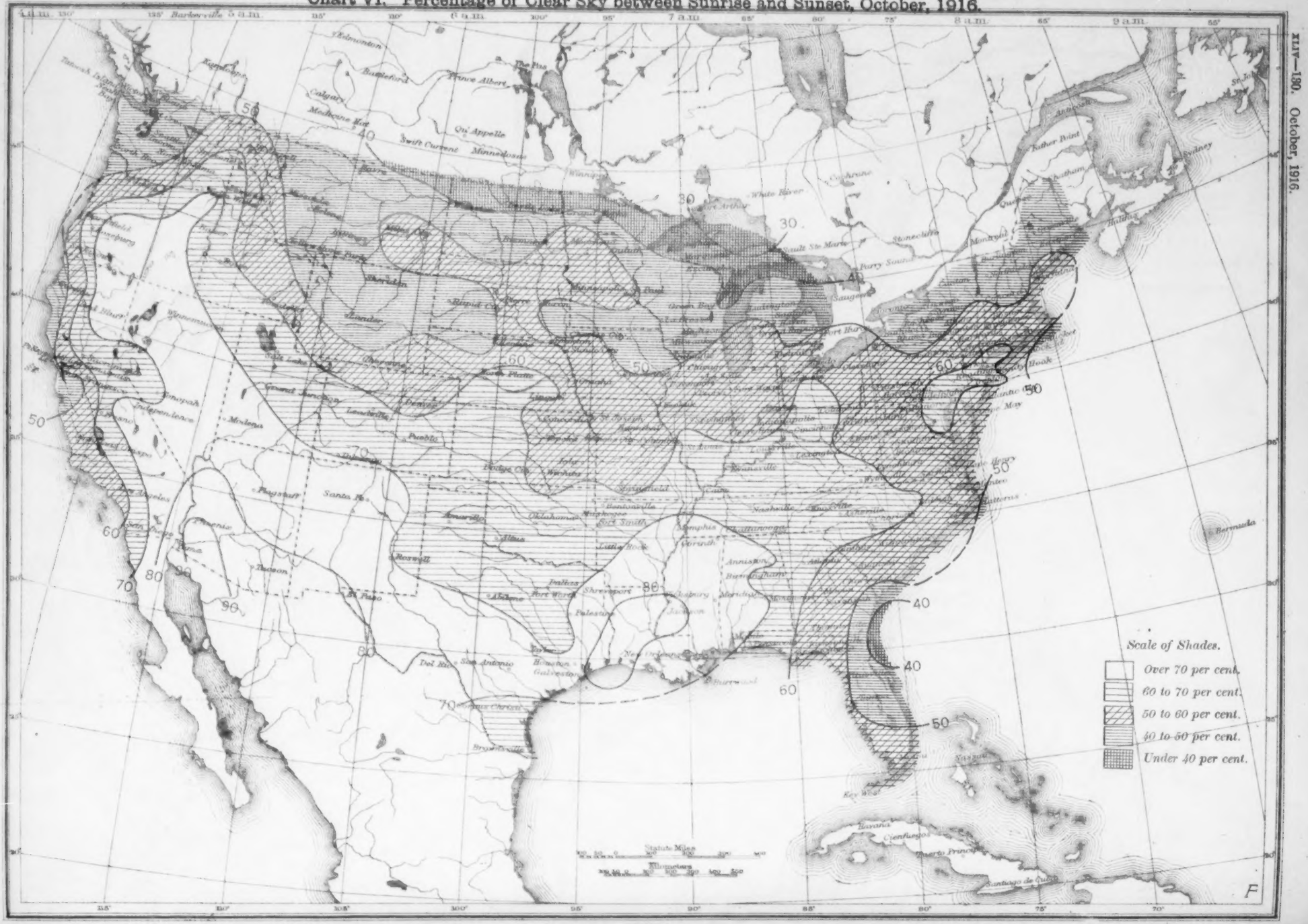
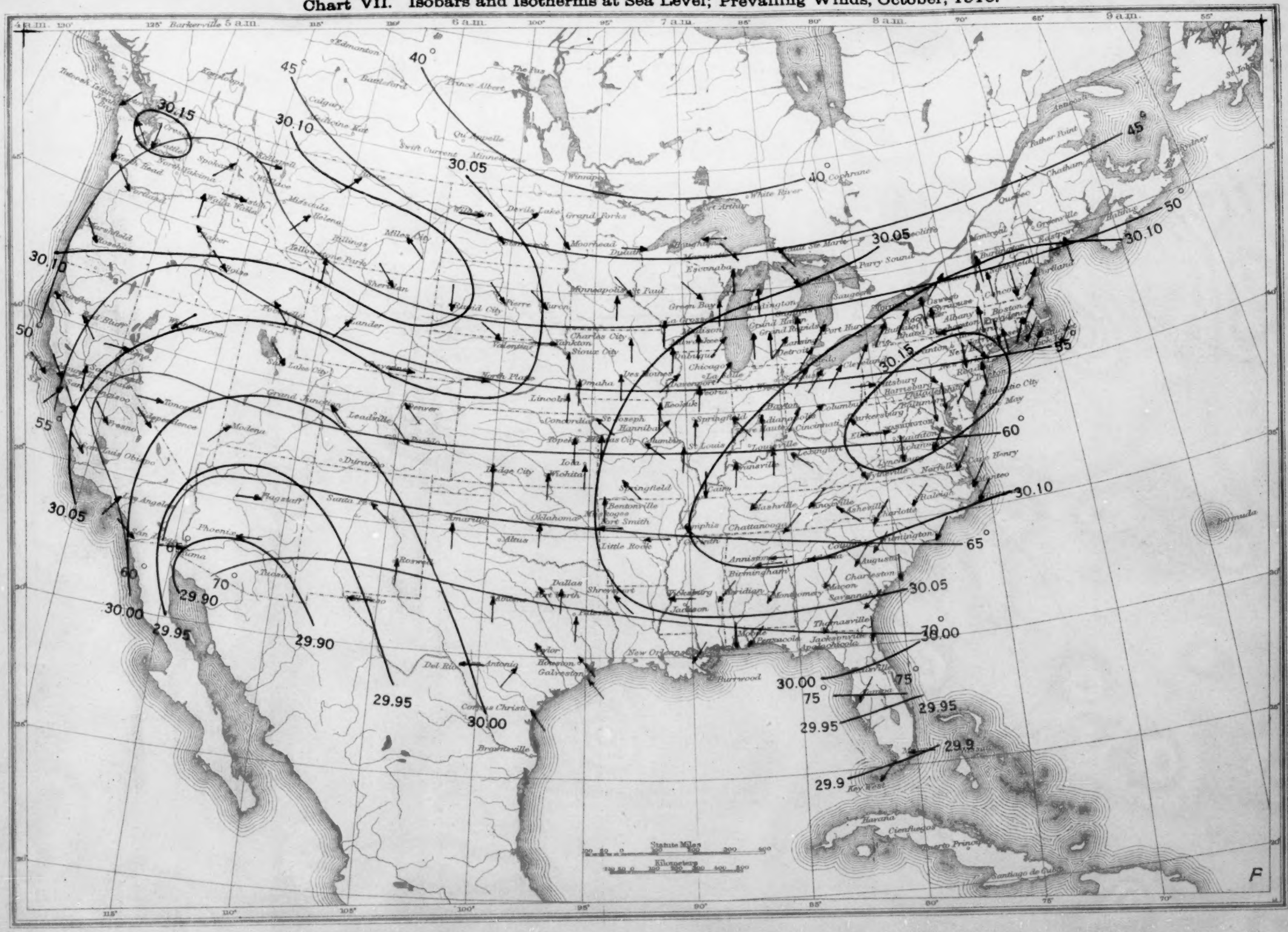


Chart VII. Isobars and Isotherms at Sea Level; Prevailing Winds, October, 1916.



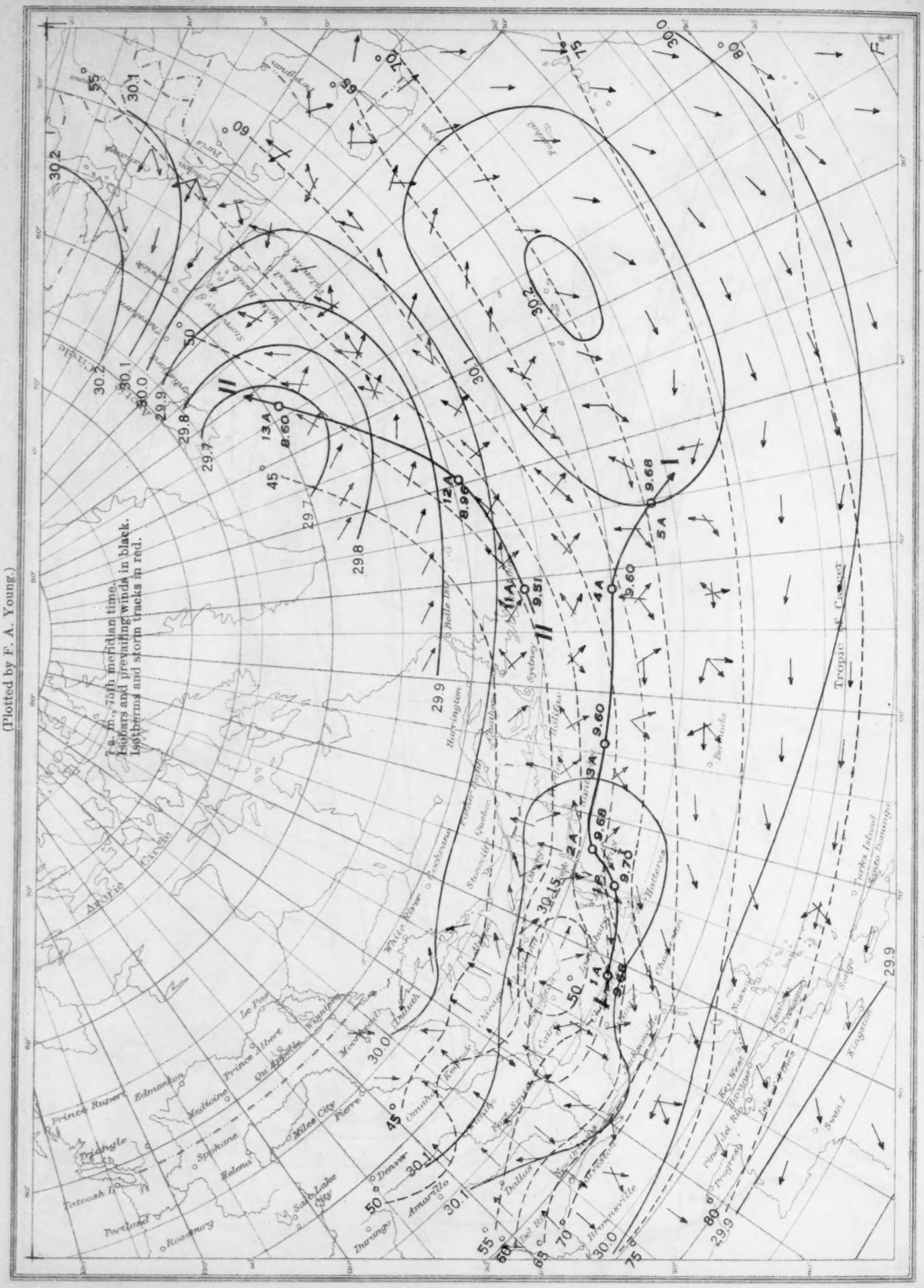


Chart IX. Means of Meteorological Data for North Atlantic Ocean, October, 1915.

(Plotted by F. A. Young.)